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Local farmer knowledge of adaptive management on diversified vegetable and berry farms in the northeastern US

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LOCAL FARMER KNOWLEDGE OF ADAPTIVE MANAGEMENT ON DIVERSIFIED VEGETABLE AND BERRY FARMS IN THE NORTHEASTERN US

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ABSTRACT

Agricultural adaptation to climate change is notoriously context specific. Recently updated projections for the Northeastern US forecast increasingly severe and erratic precipitation events which pose significant risks to every sector of agricultural production in the region. Vegetable and berry farmers are among the most vulnerable to the risks of severe precipitation and drought due to the intensive soil and crop management strategies which characterize of this kind of production. To successfully adapt to a changing climate, these farmers need information which is tailored for the unique challenges of vegetable and berry production, framed at the level of climate impacts, and delivered through the familiar lexicon used by farmers in the region.

My approach is grounded by partnerships with farmer networks to inform both the relevance of this information and my outreach strategy for sharing results. This research presents complimentary quantitative and qualitative data sets on adaptive management, and highlights the insight of farmers voices on innovative and promising solutions for managing climate related risks.

The goal of the project was to create usable information for producers through a Farmer First approach which privileges the voices and experiences of farmers in determining the information and resources they need. As part of a broader project, this thesis analyzed the results of a regional survey of vegetable and berry growers conducted over the winter months of 2017-2018. The first chapter reviews theoretical foundations for academic study of agricultural management and climate change, with a focus on information usability. The second chapter applies theories of adaptation and resilience to identify agroecological principles for adapting farm management to water extremes and innovative practices emerging in the region. The third chapter uses a regression modelling approach to explore how adaptive management practices vary across site specific characteristics.

Our analysis identifies trends and principles for adapting to water excess and water deficits on diversified vegetable and berry farms in the Northeast. The research findings highlight how site characteristics influence the selection of adaptive management practices on farms in the Northeast.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

This thesis manuscript presents scholarly contributions from the New England Adaptation Survey. The survey is part of a two-year project to create information about climate adaptation for vegetable and berry producers in the northeastern US. Outreach contributions and focus group work in the second year are connected to the survey, but not shared extensively in this manuscript.

The project has been influenced by communities of practice at the University of Vermont and the USDA Northeast Climate Hub. This research endeavor was inspired by the confluence of a few things; first my experience working for the ALC as a liason the USDA Northeast Climate Hub and talking to project stakeholders at the end of a research phase of a PAR project focused on farmers in Vermont. Second, immersion in PAR theory and practice at the ALC. Third, my experience in Sarah Heiss's qualitative methods course which gave me the confidence in my ability to conduct and write original research. The original research I conducted under her guidance was on the co-production of knowledge among farmers and extension professionals, and the lessons gleaned from that research have been woven through the subsequent research.

This data was collected as part of a two-year project at the University of Vermont called "The New England Adaptation Survey". This is funded by USDA SARE and supported by an ongoing partnership between UVM and the USDA Northeast Climate Hub. The New England Adaptation Survey was developed in collaboration with farmer groups to provide usable information about adaptive management for vegetable and berry farmers across the Northeastern US region. The survey draws upon the knowledge and experience of farmers in the region to identify information on adaptive management and then share results back in the second year via collaborating organizations in Vermont, New Hampshire, Maine and Massachusetts. Collaborating organizations include University of Vermont Extension, Maine Organic Farmers and Gardeners Association, Northeast Organic Farmers Association of Vermont, Northeast Organic Farmers Association of New Hampshire, Rural Vermont, Community in Support of Agriculture (Massachussetts), New England Vegetable and Fruit Conference, New England Vegetable and Berry Growers Association, Maine Tree Fruit Growers, and the Vermont Vegetable and Berry Growers Association. These established farmer organizations facilitate the interface between research and stakeholders, and offer valuable interpretation and framing of the results for key audiences.

This paper draws on the results of a survey conducted with vegetable and berry producers across the region to explore how adaptive management for extreme precipitation events is influenced by site-specific characteristics and perceptions of weather risks. This research fills a research gap by identifying adaptive management strategies of a specific producer type and seeks to create information that will be useful to both the farming community and the technical experts who support them. This project set out to answer a broad research question:

- *What information do farmers and outreach professionals need to best support vegetable and berry growers in adapting to the impacts of climate change?*

To this end, this paper seeks to answer the following questions which are a subset of the larger research question:

- *What adaptive strategies are already in use among diversified vegetable and fruit producers in the Northeast to manage for the risk of heavy precipitation?*

- *Do adaptive management strategies differ based on the site-specific vulnerabilities of farms?*
- *How concerned are these farmers about climate-related risks?*

A goal of creating outreach and information geared towards farmer usability guided this project, from the original study design to the way I balanced my time towards listening to farmers, showing up at their events, and delivering information back to them. A report based on the results of the survey was completed and shared with farmer audiences starting in October 2018, and can be found on the SARE website.

CHAPTER 1: COMPREHESIVE LITERATURE REVIEW

In this chapter, I review concepts and research that set the foundation for my research and thesis topic. I start by exploring vulnerability theory and the unique sensitivity and exposure of growers in the Northeastern US to identify the climate change impacts for vegetable and berry producers. I dedicate a section to explaining adaptive capacity, as the final element of vulnerability with the most leverage for change and support from research and outreach relationships, and follow it with laying out common theoretical frameworks that have been used for adaptation. From this broad introduction to adaptation, I follow with a review of adaptive management in agriculture with a focus on the Northeastern US. The latter portions of this chapter explore prior research on how participatory approaches can increase the usability of information about climate change, and the role of farmer networks in supporting learning and innovation. The literature review closes by identifying the influence of Farmer First and interpretivist approaches on my research.

The use and advancements of conceptual frameworks for understanding vulnerability, adaptation, resilience and adaptive capacity have exploded in the last decade. This trend is tied to global cooperation on addressing the drivers and impacts of climate change, and the UN goals of sustainable development with associated funding. The majority of this work on adaptation and resilience frameworks has been applied at the community scale in the developing world. Elsewhere the application of resilience, vulnerability and adaptation frameworks is so abundant and diverse that conflicting definitions of core terms have emerged, requiring scholars to identify which conceptual family they ascribe to.

Research on adaptation to climate change was bundled with mitigation until the late 1980s, and was initially characterized by evaluating the merit and risk-management capability of adaptations to inform policy audiences (Wall, Smit and Wandel, 2007). The last three decades of scholarly literature on climate change adaptation have been abundant and diverse, including global and regional assessments, case studies, advancements in theory, physical and biological variables, modelling, as well as a notable surge in efforts to include behavioral psychology, communication and sociological perspectives.

Wall, Smit and Wandel (2007) typify the abundance of scholarship on climate change adaptation into three categories; impact-based, context-based, and process-based. Impact-based approaches focus on questions of what the impacts of expected climate change are and what adaptations could address climate impacts. Context-based approaches compliment this kind of inquiry by assessing the conditions that facilitate or constrain adaptation. The third approach, process-based inquiry, is concerned with how to facilitate adaptation in practice, and this is where I place my own work. This is akin to what Moser and Boykoff (2013) call an "adaptation approach" to identifying successful adaptation, which focuses on a specific sector and seeks to address known and evolving risks.

1.1 Vulnerability, exposure and sensitivity

In this section, I review the concepts of vulnerability, exposure and sensitivity, with a special focus on relevance to vegetable and berry producers in the Northeastern US.

Theoretical foundations for understanding the vulnerability of agricultural operations to climate change have been advanced by large institutions such as the IPCC, USDA, and the United Nations (Cardona et al., 2012; Lengnick 2015; Janowiak et al., 2016; Tobin et al., 2015). In this study, I use a common definition of vulnerability as the combination of exposure, sensitivity, and adaptive capacity (Lengnick 2015; Cardona et al., 2012; Smit and Wandel 2006), where exposure is understood as the external climate impacts a system is subjected to, sensitivity is the way and degree to which the system is effected by those impacts, and adaptive capacity is the ability for the system to respond to, change and persist through shocks and stressors. Together, exposure and sensitivity define the potential impact of climate change on a farm (Figure 1). This definition is useful because it can be integrated with transdisciplinary frameworks for risk evaluation and resilience, (such as the Community Capitals Approach (Flora et al., 2016) and the Sustainable Livelihoods Approach.)

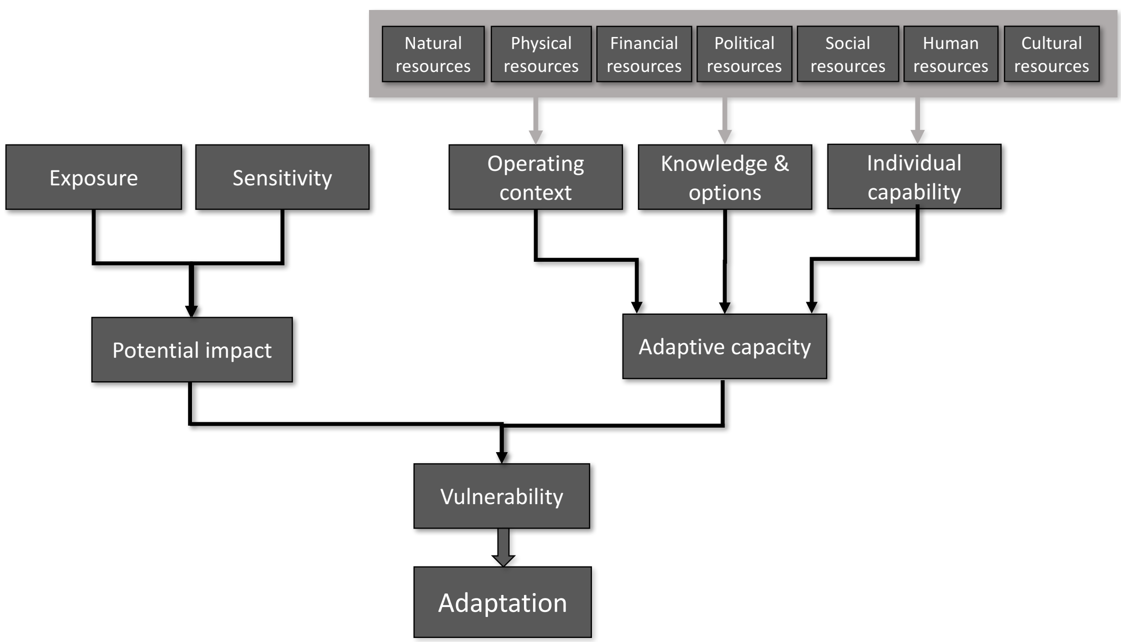

Figure 1. Factors influencing vulnerability and adaptation of agriculture to climate change. The figure combines the vulnerability concept from the USDA via Lengnick 2015, and adds resource categories from the Cultural Capitals Framework (Flora et al., 2016) to illustrate drivers of adaptive capacity.

Agriculture in the Northeast has a high level of exposure to extreme and heavy precipitation events. Historic trends show that the region has already experienced a 71% increase in very heavy precipitation events since 1958 (Kunkel et al., 2013). Projections suggest increasingly frequent flooding (Kunkel et al., 2013), as well as increasingly heavy downpours and extended periods of rainfall through the coming century (Wolfe et al., 2018; Melillo et al., 2014). Some of the most agriculturally productive soils are in the floodplain, and the increase in heavy rain events also means an increase in flooding events on farms in the floodplain.

Accurate and downscaled climate information models presented for the impacts of concern to local communities make climate information more useable (Li et al., 2018). The most recent downscaled vulnerability and agricultural impact assessment for the Northeast by Wolfe et al., (2018) projects that under the "business as usual" emissions scenario (RCP 8.5) the frequency of rainfall events greater than 5 cm will increase by 50 and 75% between 2040- 2069, and double by the end of the century. Precipitation events greater than 10 cm are projected to double and triple in frequency along much of the Northeast by the end of the century. Seasonal precipitation patterns which emerge from this modeling work indicate that most of the increased precipitation will occur in winter and spring months. Novel water deficits and periods of summer drought are also projected to increase in the region due to increased potential evapotranspiration and stagnant or declining precipitation occurrence during summer months (Wolfe et al., 2018). Of importance, these downscaled projections by Wolfe et al., (2018) indicate that alternate carbon pathway scenarios with reduced anthropogenic contributions to atmospheric CO2 would reduce the projected catastrophic level impacts on agriculture. Although, even the most optimistic RCP projects that extreme precipitation events will increase for the region.

These risks are shared by growers across the region, but the unique characteristics of each agroecosystem will influence the individual sensitivity of a site to extreme weather impacts. Soil erosion rates are influenced by slope, soil grain size, bulk density, surface roughness, runoff length, velocity, shear stress of overland flows, and the friction coefficient of soils (Liu et al., 2001). Agricultural production in the Northeast occurs in varied soils and sites, from steep rocky slopes to rich river floodplains, thus offering a unique context to compare how management strategies differ by site characteristic. Some of the most agriculturally productive soils are in the floodplain, and the increase in heavy rain events also means an increase in flooding events on farms in the floodplain.

The intense crop and soil management which characterizes diversified fruit and vegetable farmers make them particularly sensitive to extreme precipitation patterns (Walthall et al., 2012). Soil in annual vegetable production systems is commonly disturbed frequently throughout a single season for purposes of soil building, bed preparation, and crop turnover. Many farmers also till or hoe soils consistently through the season to control weeds. This strategy is particularly prevalent among organic farmers, who employ this strategy in the stead of chemical weed controls (Schonbeck 2010). These activities leave soils uncovered and disturbed, where rain and runoff readily erodes soil and damages soil structure.

The potential impacts for vegetable and fruit producers are many and vary by specific crop, because each crop has unique temperature and water thresholds for optimal productivity and damage. The direct impacts to crops from excessive water and drought together account for over 70% of all crop loss reported to the USDA-FSA from 2013 to 2016 across the entire NE for all years and all crops (Wolfe et al., 2018).

Excessive and repeated rainfall accompanied by storm water surges leave agricultural soils and systems prone to erosion, significant soil losses, nutrient depletion and direct crop impacts (Janowiak et al., 2016). Maturing crops can be damaged by direct moisture on fruit, which causes cracking in the sun, most notably in high value crops like fruits and tomatoes. Hail and extremely heavy precipitation often damage leafy crops and directly, and can cause fruit to drop or spoil from soil splash. Despite overall warming offering an early start in the spring, increased precipitation in spring months has caused delayed planting due to cold and saturated soils (Wolfe et al., 2018). Additionally, heavy rainfall is associated with restricted plant growth and yields due to poor oxygen levels in the soil, and increased incidence of fungal and root diseases (i.e. *Pythium & Rhizoctonia*). Increased precipitation also aids in the spread of leaf-borne diseases, such as *Phytopthera infestans*. The negative impacts of excess water in soil include erosion (Favis-Mortlock et al., 1991), nutrient leaching (Ramos et al., 1994) and workability (Rounsevell and Brignall, 1994).

Water deficits can cause many different types of crop stress and yield declines, though impacts vary by species and degree of exposure (Korres et al., 2016; Blum 1996). Water deficit stress limits the growth, performance and productivity of plants more than any other environmental factor (Shao et al, 2008). Crop stress due to drought conditions is often attributed to stomata closure which inhibits photosynthesis (Griffin et al., 2004), leading to overall reduced plant growth, mass and lifecycles (Blum 1996; Pace et al., 1999). If water deficits correspond with the timing of flowering or seed development, it can lead to infertile pollen, reduced fruit set, or aborted seed. Water deficit stress also makes plants more vulnerable to pest and disease, and can result in plant mortality. For farmers that have not installed irrigation, drought can have severe impacts on crops, or require costly infrastructure investments to prepare for the risk of drought.

The way farmers adapt their farm management for the increased incidence of extreme weather risks is influenced by the aforementioned exposure, sensitivity and impacts, but also limited by their adaptive capacity.

1.2 Adaptive capacity

The capability to make change with external forces in mind has been termed adaptive capacity. In contrast to ecosystems which respond to impacts through genetic transfers and storage, farms and forests are also governed by the decision-making of humans who employ learning, reasoning, and communication to respond to external forces (Norberg and Cumming, 2008; Holling et al., 1998). Adaptive management decisions by farmers and foresters are limited by the combination of assets and knowledge that are available to draw upon. These strategies are also influenced by the unique operating context and site-specific characteristic of a farm or forest, how vulnerable they are to the impacts of climate variability, and the perceived nature of climate-related risks. Understanding the vulnerability complex and limiting factors for adaptive decision-making through a livelihoods asset framework can help identify key leverage points for intervention and capacity building (Nelson et al., 2010).

Adaptive capacity, as a function of farmer capability, emerges from the management of basic agricultural asset categories (Lengnick, 2015) and is widely understood through a livelihood complex in international studies on smallholder farm resilience. Agricultural management for effective adaptation and mitigation depends on both farmer willingness and capacity to pursue such actions (Howden et al., 2007; McCarl, 2010). The intent to make changes is the last crucial element to adaptation, and for climate-risk management, this poses a unique challenge to agricultural communities within the United States. In developing and developed countries elsewhere in the world, limiting factors are associated with farmers' struggle with capacity, but in the United States, adaptive management can also be limited by climate science skepticism (Chatrchyan et al., 2017).

To support land managers in making adaptive decisions it is important that we consider and develop our understanding of how farmers view climate adaptation measures (Arbuckle et al., 2013). Developing an agroecosystem's capacity to both mitigate and build resilience to climate change requires that farmers have the time and resources to invest in management changes, as well as access to information about the best strategies to employ. The capability of farmers in the Northeast to make change with external forces in mind is a function of available resources combined with the social and ecological factors which influence decision-making. Among the many indicators that researchers have identified, knowledge is an important determinant in adaptive capacity, as are access to financial resources, ecological assets, social networks and physical infrastructure (Williams et al., 2015).

Adaptive management strategies on farms are part of a complex and site-specific decision-making context that varies by individual and community scales (Lyle, 2015). For farmers in the Northeastern region, previous experience is an important factor in determining perceptions and beliefs about climate change and climate related risks (Takahashi et al., 2016), which are important drivers of climate risk management decision making (Chatrchyan et al., 2017). The cumulative effects of recurrent disasters can substantially affect livelihood options and resources and the capacity of societies and communities to prepare for and respond to future disasters (Cardona et al., 2012). Agricultural producers have been managing farms productively through the volatile climate characteristics of the region in recent decades, indicating that farmers have already used many strategies to successfully adapt their farm management to the increased risk of heavy precipitation events in the northeast (Lane et al., 2017; Schattman et al., 2016; Jemison et al., 2014).

1.3 Adaptation theory

I will briefly introduce three conceptual frameworks that are useful for my research. First, is the concept of coping range (Fussel, 2007), which predates the adaptation frameworks and applies well to the household and farm scale. The second is the Adapt IT[2] framework, most recently advanced by Hadartis et al., (2017) which synthesizes the highly referenced conceptual work of both Mark Pelling (2010) and Park et al., (2012). The third is the resilience framework recently published in a SARE bulletin by Laura Lengnick (2018), which aligns well with other resilience frameworks, and given the high level of exposure this document and author are receiving, is a conceptual graphic that my farmer and extension audiences may be familiar with (Figure 2).

I think the concept of coping range is useful for my research, in describing the range of precipitation patterns which farmers in the northeast are prepared to deal or cope with.

When drought or heavy precipitation patterns fall outside the expected range of climatic conditions for the region, farms are dealing with conditions outside their coping range, which they are not adapted to. As Fussel (2007) explains, during the period subsequent to extreme conditions outside the coping range farmers decide whether or not to adjust and adapt to a new expectation of the climate. Those that do not invest in adaptations are assumed to either expect to take losses in future conditions, or expect that this type of extreme shock is unlikely to occur again. Coping, as a concept, precedes adaptation frameworks and lexicon by about 30 years and continues to be used as a parallel concept in different epistemic communities (Pelling 2011).

Adaptive capacity is context specific and adaptations are manifestations of adaptive capacity (Smit and Wandell 2006). According to Fussel, (2007) adaptations can be both reactive or proactive, that is, motivated by prior experience, or made in anticipation of a shock or stress, but the distinction between reactive and proactive adaptation may be fuzzy in practice. Fussel's exploration of adaptation frameworks goes on to observe that, "the diversity of adaptation contexts implies there is no single approach for assessing, planning, and implementing adaptation measures. Adaptation assessments must therefore flexibly apply different methodological approaches to produce knowledge that is relevant in a particular decision context." (Fussel 2007, 276). For this research, it is important, therefore that we familiarize ourselves with the types of adaptation frameworks that could be employed to support our communication of adaptation in this context. I think it is equally important that we use an interpretive research paradigm that allows the nature of adaptation in this context to shine in its own light through the perceptions and experiences of farmers.

The Adapt IT[2] framework (Hadartis et al., 2017) synthesizes work by many, most notably Mark Pelling (2010) and Park et al., (2012), to typify adaptations by essentially the amount of change they make. *Incremental* adaptations constitute changes which maintain the integrity of a process or system and sustain the same organizational objectives (Park et al., 2012). Adaptations in agriculture are primarily characterized by adjustments to management within exiting framework of farm goals and processes, which constitute incremental adaptation (Pelling et al., 2015). The wealth of scholarship on adaptation presents a notable wave of advocacy for considering transformative adaptation (Gillard et al., 2016; Pelling et al., 2015; O'Brien, 2012; Park et al., 2012;). Transformative adaptation is defined for agriculture as, "major, purposeful action undertaken at the farm or supra-farm level in response to potential or actual climate change impacts and opportunities in the context of other drivers" (Rickards and Howden 2012, 240). However, there is evidence that transformative adaptation in agriculture is wrought with barriers and challenges, such as being difficult, complex, risky and costly and sometimes unsuccessful (Jakku et al., 2016). A third type of adaptation completes this theoretical framework—transitional adaptation, which is often simply defined as something in between incremental and transitional adaptation. Hadartis et al., (2017) calls transitional adaptation an incomplete transformational adaptation, a phase that is passed through to get to transformation which is still reversible and shares the same transformative goals, but is reversible.

Alternately, the common tripartite theory of resilience which has been applied in the US (Lengnick, 2018) and in development contexts (Caswell et al., 2016), emphasizes changes as investments in capacities to deal with shocks and stressors. Caswell et al.,

(2016) draw upon a wealth of research and international development experience to identify three resilience capacities as absorb, adapt or transform. Alternately, but similar, Lengnick (2018) who has geared her work towards farmers and agricultural advisors in the US, organizes resilience capacity as the ability for a farm to respond, recover or transform (Figure 2). These frameworks offer a common language to discuss the capacities that farmers are investing in when they make adaptive management decisions. Research has yet to characterize agricultural adaptation in the Northeast based on these typologies, though we anticipate new findings from Coleman et al. in the coming year.

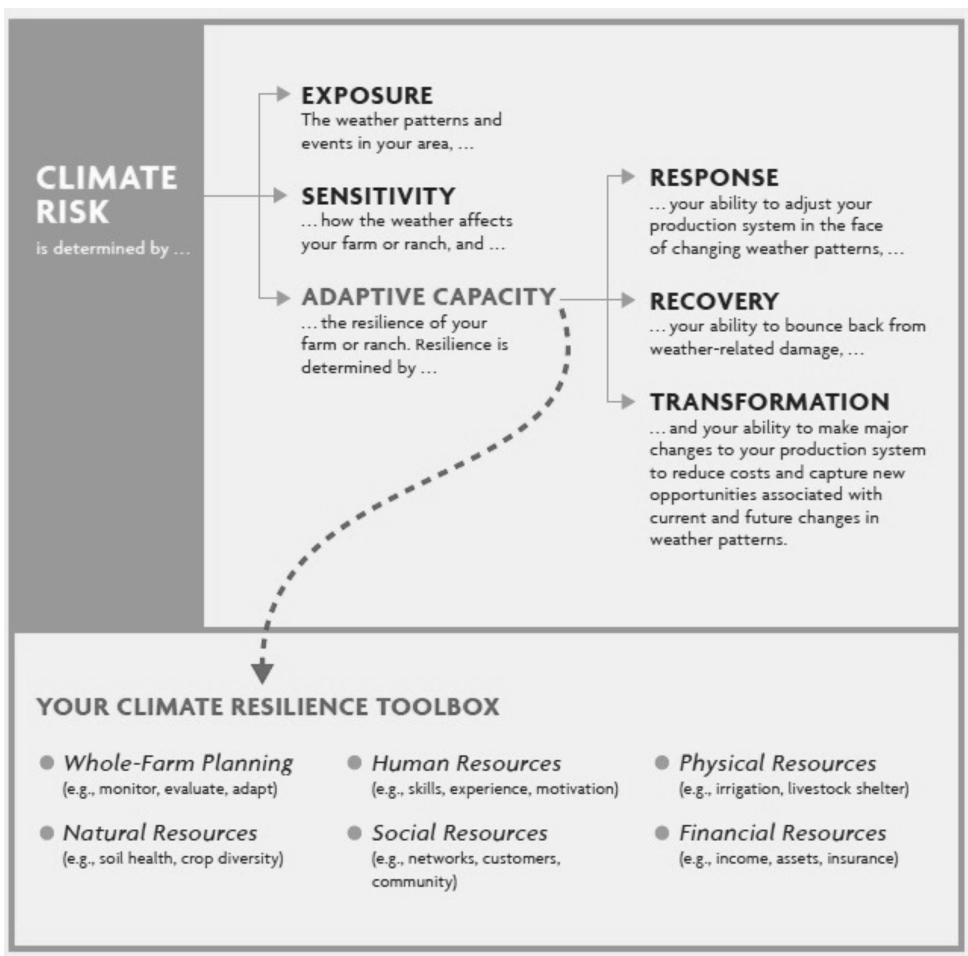

Figure 2. Conceptual framework for understanding climate risk and resilience on farms in the US. Adapted from Lengnick 2018.

1.4 Adaptive management

Among the abundant scholarship and frameworks for adaptation and resilience, the IPCC reports dominate definition and broad application, so I have used their definition of adaptive management: "A process of iteratively planning, implementing, and modifying strategies for managing resources in the face of uncertainty and change. Adaptive management involves adjusting approaches in response to observations of their effect and changes in the system brought on by resulting feedback effects and other variables," (Barros et al., 2014).

Various recent research efforts have documented adaptive management strategies in the Northeast, which buffer farms from the risks associated with increasingly variable weather and climate change. General recommendations have been made, based on prior research, as to the effectiveness of conservation practices, such as cover cropping, and riparian buffers, (Janowiak et al., 2016; Tobin et al., 2015; Schattman et al., 2015). Extensive research has also been conducted on the promise of individual management strategies like crop diversification (Lin, 2011) and cover crops (Kaye and Quemada 2017). Crop selection is one adaptive management strategy which has been documented to be in use across agricultural production types and locations. Crop selection has been documented as a climate adaptation among farmers in South America (Seo and Mendelsohn, 2008), Canadian prairies (Bradshaw, Dolan and Smit, 20i4), and Bangladesh (Moniruzzaman, 2015). Prior research indicates that crop selection and planning are predicated upon spatial organizing of farmland features into appropriate crop-management blocks (Drury et al., 2013). Although research indicates that cropping patterns have become more specialized since 1994 (Bradshaw, Dolan and Smit, 2014) diversification as adaptive management strategy has been both documented as an adaptation strategy and advocated by experts for manage on-farm risk (Bradshaw, Dolan and Smit, 2014; Schattman et al., 2015). Intercropping and agroforestry systems have exhibited enhanced soil nutrient pools, microbial resilience, and water stress tolerance when compared to control treatments under drought and flooding conditions (Rivest et al., 2013). Soil that has received compost and organic matter additions exhibits increased soil moisture, available P, and plant available N during drought conditions. (Ng et al., 2015). Books authored in the northeast document innovative approaches to climate resilience that are not yet found in scholarly literature, but should be relevant to transdisciplinary research approaches, notably water harvesting and holistic site planning methodologies (e.g. Jacke and Toensmier 2005; Falk 2013; Trought 2015).

Research on adaptive management in Northeastern agriculture documents farmers as resilient and adaptive, and identifies strategies which are being employed to manage the risks associated with climate change (Lane et al., 2018; Schattman et al., 2015; Jemison et al., 2014). In Vermont, climate risk management strategies reported at the farm scale include (1) diversification of markets, production, household income and land base, (2) sustainable soil management, including water management in soils, and (3) innovative cropping systems (Schattman et al., 2015). Research by Jemison et al. (2014) in Maine identified over 40 different strategies which farmers are using to manage for climate risks. Importantly, Jemison et al. (2014) notes that climate risk management considerations differ based on operating context, which refers to the combination of site specific characteristics, scale, production type, policy constraints, access to resources, and other pressures which drive decision-making. Recent research on farmers in Pennsylvania and New York (Lane et al., 2018) identify planting dates, changing plant varieties, diversifying crops, installing tile drainage, utilizing cover crops and switching to reduced tillage or no-till practices as the most prevalent adaptive practices in use.

The vulnerability and adaptation of agriculture in the Northeast US has received attention from researchers and agricultural support specialists, such as land grant extension program, farmers associations, and the USDA Northeast Climate Hub, yet research on adaptive management in the Northeast has not yet addressed the unique needs of vegetable and berry farmers. The work of experts and scholars to create information on adaptive management for agriculture in the Northeast is well captured in recent recommendations from an impact assessment by Wolfe et al., (2018) and the development of a list of potential best management practices from Schattman et al., (2018). Our research is most closely aligned with research conducted by Jemison et al, (2014) which captures the suite of practices farmers consider to be adaptive. The northeast regional climate vulnerability assessment (Tobin et al., 2015) and adaptation workbook (Janowiak et al., 2016) suggest adaptive management strategies for vegetable growers, and state specific research has been done on the adaptive management of farms in general. However, there is no information on what vegetable and berry farmers are doing or are planning to do (Schattman et al., 2015). Understanding how local agroecological and farm system context influence climate risk management decisions is critical information for technical assistance and other programs that seek to support these farmers in successfully adapting to climate related risks.

Agroecological perspectives on climate adaptation and resilience in agriculture are limited, though promise to shed light on sustainability within the sphere of climate and agriculture research. Agroecological principles have yet to be applied to this kind of research in the US, though they have been applied in international contexts. Agroecological analysis by Eric Holt-Gimenez (2001) revealed that sustainable farming methods far outperformed conventional farming practices in resisting the impacts of Hurricane Mitch. This study presents the concepts of resistance and resilience as two different properties of agroecosystems, the former being the capacity for the system to resist impacts from natural stressors, whereas resilience is associated with the systems' capacity to recover. Holt-Gimenez (2001) cites Gliessman (1998), Pimm (1984) and Herrick (2000) as sources of this agroecological resilience/resistance theory. The study applies a large set of paired empirical data from 800 farmers through Nicaragua's farmer-to-farmer network. The use of contoured tillage, contoured ditches, terraces and contoured plantings account for functional soil and water conservation through the storm event. Many functional resistance benefits were attributed to cover cropping, integrated pest management, compost additions, reduced inputs, agroforestry, vegetative strips, and alley cropping. The focus on practices in this study found that there are important thresholds in storm intensity and slope at which resistance collapses. Holt-Gimenez (2001) also documented a lag time in economic benefits from agroecological practices.

Altieri and Nichols (2017) suggest looking to resuscitate traditional farming strategies for agroecological resilience, namely biodiversification, soil management and water harvesting. Traditional farming methods have used raised fields to secure production in wet and water-logged soils, as well as furrows and ditches in drylands to capture and hold water in agricultural fields (Altieri & Nichols, 2017). Diversification in crop genetics, and in spatial and temporal heterogeneity, have been observed to increase to maintain the integrity of traditional farming systems through reducing erosion, increased recovery time and enhanced soil health.

Adaptive management practices are not isolated and static. Interactions and functional overlap among practices observed in the Holt-Gimenez study (2001) were also documented in the more recent case study in Canada by Hadartis et al., (2017). Hadartis et al., (2017) noted that some adaptations can set boundaries for others, and investing in one strategy often limits the capacity to change direction in future adaptive management decisions.

Agroecology as a science, practice and movement is concerned with supporting transitions towards more sustainable food systems. Principles of agroecology shed light on strategies for farm scale resilience to climate change that transcend site characteristics and contextual factors, and thus they offer a rubric for communicating and comparing adaptation practices to broader audiences. Scarborough et al. (2015) identified twelve agroecological principles for resilience which can be used as a point of comparison for our study (Table 1). A comparison of how on-farm adaptations reflect these agroecological principles can identify leverage points for communication and innovation, as well as important gap and resource needs.

Table 1. Agroecological principles for climate resilience. Adapted from Scarborough et al., 2014.

	Preserve and enhance agroecosystem biodiversity
	Enhance soil fertility and nutrient cycling

	Conserve water
	Support ecological pest- and disease- regulating mechanisms
	Minimize use of external synthetic inputs to reduce cost, dependence and harm to agroecosystem
	Manage beneficial ecological relationships
	Maximize renewable energy potential
	Diversify livelihoods to minimize risk exposure to shocks and stresses
	Prioritize and enhance local food security, nutrition and health
	Integrate local and scientific knowledge through appropriate practices and technology
	Strengthen and empower local organizations
	Facilitate shared governance of natural resources

1.5 Forcings and feedbacks

Agricultural management and agroecosystem structures are changing and adapting to the pressures of a changing climate and a changing world. These adaptive decisions and land use changes have implications for changing biogeochemical cycles that influence climate feedback cycles (Ball 2013). Rough estimates for the global mitigation potential of farming systems to sequester carbon estimate a possible 3.5–4.8 Gt CO2 reductions, which accounts for 55–80 % of total global emissions from agriculture, and a two thirds reduction of N2O (Niggli et al. 2008). However, many adaptive strategies can have net negative impacts on climate forcings, such as increasing the areas in production by developing conserved or forested lands. Importantly, adaptive management practices often have tradeoffs in terms of mitigation potential, but many have documented net positive benefits for reducing greenhouse gas emissions, sequestering carbon and increasing albedo (Kaye and Quemada, 2017). It is the role of policymakers and technical advisors to understand the implications of agricultural management changes on climate forcings and feedbacks, and support farm managers in mitigating the drivers of climatic change as they adapt to increasingly severe, complex and uncertain climate-related risks.

Academics stand somewhat divided on the merit of considering mitigation in discussions of climate adaptation. Altieri & Nichols (2017) place mitigation as a critical consideration, as do proponents of Climate Smart Agriculture, which originally intended to evaluate agricultural management for the three goals of adaptation, mitigation and food security. Others, such Schattman et al., (2016), reveal that mitigation is notably absent from farmers' risk management considerations about climate change. Studies on climate change communication emphasize the importance of 'knowing your audience' and communicating at the level of local and direct weather impacts rather than systemic climate change (see Easton & Faulkner, 2016). Research from the Yale Program on Climate Change Communication emphasizes that locally specific information based on climate impacts, through peers or networks with whom they have trusted relationships and share values, is an effective means of encouraging behavior change (Kahan et al., 2011). Some say that it is more effective among skeptical audiences than simply providing science-based facts about climate change (Chatrchyan et al., 2017; Kahan et al., 2011).

1.6 Information Usability

This disparity between the creation of significant and critical climate information, and its actual application or use by stakeholders has been referred to as the climate information usability gap (Kirchhoff et al., 2013; Lemos et al., 2012). This topic has prompted a wave of recent and current research into how to bridge the gap between the creation of scientific climate knowledge and its use by relevant stakeholders in society (e.g. Moss, 2016; Kalafatis et al., 2015; Meadow et al., 2015; Eisenack et al., 2014). Scholarship examining the gap in application of climate science to decision-making, points to: 1) challenges in how decision makers perceive the salience, credibility and legitimacy of knowledge; 2) how new knowledge fits and interplays with existing practices and knowledge; 3) how challenges to climate information use may arise if scale of knowledge creations and use are mismatched; 4) how limited understanding of decision-making context may impede uptake; 5) decision-makers concerned with political tensions; and 6) psychological distancing of climate impacts (Rasmussen, Kirchhoff & Lemos, 2017; Cash et al., 2003; Lemos et al., 2012; Gordon et al., 2016, Dilling et al., 2014; Phadke et al., 2015; Weber 2006).

Integrated and participatory approaches have been advocated as an effective way to overcome the climate usability gap, deliver complex and challenging science-based information and support agricultural communities in adapting to climate change (Gurung and Bhandari2009; Kirchhoff et al., 2013; Bubela et al., 2009; Cash et al., 2006; Haywood and Besley 2013; Meadow et al., 2015). This body of scholarship is concurrent with a wave of recent literature criticizing academic knowledge for failing to serve the world outside university walls and advocating for greater emphasis on creating more usable scientific knowledge (e.g. Clark et al., 2016; Kirchhoff et al., 2013). This requires a shift in delivery models of science communication away from one-way "science deficit" or "loading dock" consultancy approaches towards two-way, collaborative and participatory relationships where stakeholders and researchers are both democratically engaged.

Approaches to bridging this gap have documented the importance of networks in supporting farmer learning for improved management (Kalafatis et al., 2015; Pelling et al., 2008; Roncoli 2006; Obermaier et al., 2009; Schneider et al., 2009; Conley and Udry, 2001), and the success of boundary organizations such as the cooperative extension system (Bruger & Crimmins, 2014). Boundary organizations can be defined as those that stabilize the science-policy interface while enhancing the interactions among science producers and end users (Kirchhoff et al., 2013). Boundary organizations bridge and broker knowledge between scientists and decision makers, and often the organizational interface manifests itself in a chain of boundary organizations, or a boundary chain (Kirchhoff et al 2015; Lemos et al., 2014). In particular, extension programs have been cited as crucial links in boundary chains that share socially relevant outcomes of scientific outputs between farmers and policy makers (Prokopy et al., 2015; Bruger & Crimmins, 2014; Meinke et al., 2006).

Information access is associated with increased adaptation and helps land managers navigate decisions about which management changes will help them manage weather related risks (Hansen et al., 2007; Ziervogel and Ericksen, 2010; Wood et al., 2014 a). When evaluating new information, farmers and foresters place greater weight on the personal relationship and reputation of individuals than they do professional titles (Wood et al., 2014 b; Hujala et al., 2009). Farmers also privilege farming experience, and develop knowledge with empiricist rather than rationalist techniques (Wood et al., 2014 b). Rather than applying principles (rationalist), an empiricist approach means that farmers compare and contrast examples. This entails focusing on the details of contextual differences and similarities on-site, in order to discern what they know about management and how it can be applied to their own farm (Wood et al., 2014 b). Research on farmer networks of information flows also suggest that farmers primarily exchange new science-based knowledge within durable relationships where they are primary facilitators (Wood et al., 2014b)

My research draws on this body of research to emphasize involving stakeholders in the process of knowledge production. The intent is to positively influence the use of information in decision making (Kirchhoff et al., 2013). In practice, this means that creating groups of users with similar information needs and decision contexts, will hone potential adaptive strategies to the specific needs of that group (Kirchhoff et al., 2013). Farmers need localized and context-specific information to meet their needs. Specifically, this means; 1) localized, context specific & site-specific; 2) tied to specific climate impacts; 3) delivered via established and trusted peer networks (Chatrchyan et al., 2017; Easton and Faulkner, 2016; Morton et al., 2015; Kahan et al., 2011, Kirchhoff et al., 2013). This wisdom was also reflected in interviews I conducted with extension professional across the northeast, and drove the design of my project.

Farmer organizations play a very important but less documented role in boundary work in the US (Kroma 2006). In the northeastern US, farmer organizations and networks are often guided by a group of leaders in the farming community, including both leader-farmers and extension professionals. Adger (2003) positions farmer networks as critical structures for supporting farmers' resilience to climate change, arguing that "many aspects of adaptive capacity reside in the networks and social capital of the groups that are likely to be effected" (p 401). Farmer networks have been identified as places where new knowledge is shared and negotiated, playing a critical role in agricultural knowledge systems for driving innovation (Kroma, 2006; Hassanein et al., 1999; Obermaier et al., 2009; Schneider et al., 2009; Conley &Udry, 2001; Dolinska & d'Aquino, 2016). Farmer groups offer horizontal sharing of practical knowledge accumulated from experience (Kroma, 2006) but need access to outside information to drive innovation (Dolinska & d'Aquino, 2016). Interactive processes and trust facilitate collective action, idea testing, shared decision making and information processing into panned action (Kroma, 2006).

Social networks and organizations play an important role in influencing management choices by farmers and foresters and have the potential to influence adaptive decision making. Peer learning within communities and across networks generates a social multiplier effect which can significantly impact management decisions (Hogset and Barrett, 2010). Farmer participation in a network with collective identity impacts their actions to conform with their identified group (Klandermans et al., 2002). This network phenomenon relies upon mechanisms of social learning and social identity and has a higher impact where bonding and identity sharing is high (Hogset and Barrett, 2010). Farmers learn readily through social networks (Conley and Udry, 2001) and often prefer to learn from and validate knowledge within their peer networks, trusting their farmer peers over extension service professionals to vet new information (Hassanein et al., 1999; Foster and Rosenzweig, 1995).

1.7 Farmer First Approach

This research is informed by a farmer first approach, which recognizes farmers as experts and crucial partners in researching and innovating solutions towards the goal of sustainable agriculture (Chambers & Ghildyal, 1985). The Farmer's First proposition places farmers voices as essential to designing the development interventions they need to successful meet new and evolving challenges, and highlights a fluid knowledge system of multiple actors that influence necessary innovations (Scoones & Thompson 1994). This approach is especially important in the context of climate change adaptation, where farmer' information knowledge has proven to make considerable contributions to agricultural resilience and sustainability (Sumane et al., 2018).

An interpretive approach to agricultural research privileges the voice of the farmers through qualitative research, shares their direct quotes and frames the major themes of analysis to reflect the voices and terminology of farmers. The interpretivist paradigm seeks multiple perspectives, values iterative and emergent research processes, and promotes participatory and holistic research (Willis 2007). At its core, the interpretivism seeks to understand a particular context. The emphasis on how context influences adaptive management (Lane et al., 2018; Jemison et al., 2014) and the growing scholarship on the importance of social, cultural and individual characteristics on adaptive capacity (Wouterse, 2017; Prager and Creaney, 2017; Colloff et al., 2017; Daouda et al., 2015) make the interpretive paradigm good fit for this research arena. As well, the call by current and past scholars to place farmers voices within the research process give weight to the interpretivist case. From this I attempt to apply a Farmer's First research approach that privileges the voices of farmers in defining the interventions and support they need (Scoones and Thompson, 1994) to address climate change in the Northeastern US.

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CHAPTER 2: ADAPTING TO WATER EXTREMES ON DIVERSIFIED VEGETABLE AND BERRY FARMS IN THE NORTHEASTERN US

2.1. Abstract

Vegetable and berry production in the northeastern US is particularly vulnerable to the increasingly extreme and stochastic precipitation patterns that characterize climate models for the region. To support these producers in adapting their farm management in the face of climate change, we used a farmer-focused approach to identify innovative and promising practices for addressing excessive rain and drought, the two extreme weather impacts of highest concern to growers. Our findings document convergences and gaps between adaptation on farms in the region and the best management practices identified in prior research and advocated for by agroecologists. This research directly addresses research gaps by documenting adaptive management uniquely framed for vegetable and berry farmers in the northeast, and identifying gaps in resources used to support adaptive capacity.

2.2 Introduction

Farmers in the northeastern US are increasingly confronted with the impacts of severe and extreme weather. Climatic models for the region project heightened risk for incidence of drought, extreme precipitation events, new pest pressures, overall warming and a suite of foreboding indirect impacts, which threaten the economic viability of natural resource-based livelihoods (Wolfe et al., 2018; Janowiak et al., 2016; Tobin et al., 2015). Notably, severe drought and heavy precipitation events have caused significant crop loss in the region in recent years (Wolfe et al., 2018), and catalyzed on-farm adaptation to the increasing occurrence of these extreme weather impacts. The intense crop and soil management which characterizes diversified fruit and vegetable farmers make them particularly sensitive to the increasingly extreme and stochastic precipitation patterns which characterize climate models for the region (Walthall et al., 2012). To support these producers in adapting their farm management in the face of climate change, we used a Farmer First approach to identify innovative and promising practices for addressing these two extreme weather impacts of high concern to growers. The Farmer First approach recognizes farmers as experts and crucial partners in researching and innovating solutions towards the goal of sustainable agriculture (Chambers & Ghildyal, 1985). This proposition places farmers voices as essential to designing the development interventions they need to successfully meet new and evolving challenges, and highlights a fluid knowledge system of multiple actors that influence necessary innovations (Scoones & Thompson 1994). This approach is especially important in the context of climate change adaptation, where farmer knowledge has proven to make considerable contributions to agricultural resilience and sustainability (Sumane et al., 2018).

Our study identified agricultural networks as an ideal place to study adaptation, as a product of innovation and information sharing among farmers in the US (Sumane et al., 2018; Kroma, 2006; Hassanein et al., 1999; Obermaier et al., 2009; Schneider et al., 2009; Conley & Udry, 2001; Dolinska & d'Aquino, 2016). The study is embedded in a project guided by principles of participatory action research (PAR) and a review of literature on creating useable climate information, which emphasizes collaboration and knowledge co-production to increase the salience and legitimacy of new information (Kirchhoff et al., 2013; Meadow et al., 2015). Documenting adaptation strategies and practices emerging in agricultural knowledge networks, and delivering them back to the community, is a way to enhance the emerging conversations about climate change and provide relevant information reflecting the needs and ideas voiced by the farming community (Scoones & Thompson, 1994).

2.2.1 Climate Change Impacts

The potential climate change impacts for vegetable and fruit producers are many and vary by specific crop, because each crop has unique temperature and water thresholds for optimal productivity and damage. The direct impacts to crops from excessive water and drought together account for over 70% of all crop loss reported to the USDA-FSA from 2013 to 2016 across the entire U.S. northeast (NE) for all years and all crops (Wolfe et al., 2018).

Excessive and repeated rainfall accompanied by storm water surges leave agricultural soils and systems prone to erosion, significant soil losses, nutrient depletion and direct crop impacts (Janowiak et al., 2016). Maturing crops can be damaged by direct moisture on fruit, which causes cracking in the sun, most notably in high value crops like fruits and tomatoes. Hail and extremely heavy precipitation often damage leafy crops directly, and can cause fruit to drop or spoil from soil splash. Despite overall warming offering an early start in the spring, increased precipitation in spring months has caused delayed planting due to cold and saturated soils (Wolfe et al., 2018). Additionally, heavy rainfall is associated with restricted plant growth and yields due to poor oxygen levels in the soil, and increased incidence of fungal and root diseases (i.e. *Pythium & Rhizoctonia*). Increased precipitation also aids in the spread of leaf-borne diseases, such as *Phytopthera infestans*. The negative impacts of excess water in soil include erosion (Favis-Mortlock et al., 1991), nutrient leaching (Ramos et al., 1994) and workability (Rounsevell and Brignall, 1994).

Water deficits can cause many different types of crop stress and yield declines, though impacts vary by species and degree of exposure (Korres et al., 2016; Blum 1996). Water deficit stress limits the growth, performance and productivity of plants more than any other environmental factor (Shao et al, 2008). Crop stress due to drought conditions is often attributed to stomata closure which inhibits photosynthesis (Griffin et al., 2004), leading to overall reduced plant growth, mass and lifecycles (Blum 1996; Pace et al., 1999). If water deficits correspond with the timing of flowering or seed development, it can lead to infertile pollen, reduced fruit set, or aborted seed. Water deficit stress also makes plants more vulnerable to pest and disease, and can result in plant mortality. For farmers that have not installed irrigation, drought can have severe impacts on crops, or require costly infrastructure investments to prepare for the risk of drought.

2.2.2 Adaptation concepts

According to Fussel, (2007) adaptations can be both reactive or proactive; that is, motivated by prior experience, or made in anticipation of a shock or stress. However, the distinction between reactive and proactive adaptation may be fuzzy in practice. Fussel's exploration of adaptation frameworks goes on to observe that "the diversity of adaptation contexts implies there is no single approach for assessing, planning, and implementing adaptation measures. Adaptation assessments must therefore flexibly apply different methodological approaches to produce knowledge that is relevant in a particular decision context." (Fussel 2007, 276). For this study, we reference The Adapt IT^2 framework (Hadartis et al., 2017), which synthesizes work by Mark Pelling (2010) and Park et al., (2012), to typify adaptations by the amount of change they make. *Incremental* adaptations constitute changes which maintain the integrity of a process or system and sustain the same organizational objectives (Park et al., 2012). Adaptations in agriculture are primarily characterized by adjustments to management within exiting framework of farm goals and processes, which constitute incremental adaptation (Pelling et al., 2015). *Transformative* adaptation is defined for agriculture as, "major, purposeful action undertaken at the farm or supra-farm level in response to potential or actual climate change impacts and opportunities in the context of other drivers" (Rickards and Howden 2012, 240). However, there is evidence that transformative adaptation in agriculture is wrought with barriers and challenges, such as being difficult, complex, risky and costly and sometimes unsuccessful (Jakku et al., 2016). A third type of adaptation completes this theoretical framework—*transitional* adaptation, which is often simply defined as something in between incremental and transitional adaptation. Hadartis et al., (2017) calls transitional adaptation an incomplete transformational adaptation, a phase that is passed through to get to transformation which is still reversible and shares the same transformative goals.

Alternately, a tripartite theory of resilience which has been applied in the US (Lengnick, 2018) and in development contexts (Caswell et al., 2016), emphasizes changes as investments in capacities to deal with shocks and stressors. Caswell et al., (2016) draw upon a wealth of research and international development experience to identify three resilience capacities as *absorb, adapt* or *transform.* Similarly, Lengnick (2018) who has geared her work towards farmers and agricultural advisors in the US, organizes resilience capacity as the ability for a farm to *respond, recover* or *transform* (Figure 2). Lengnick (2018) and Caswell et al., (2016) integrate assets or resources typologies into this framework and offer a common language to discuss the capacities that farmers are investing in when they make adaptive management decisions (Figure 3).

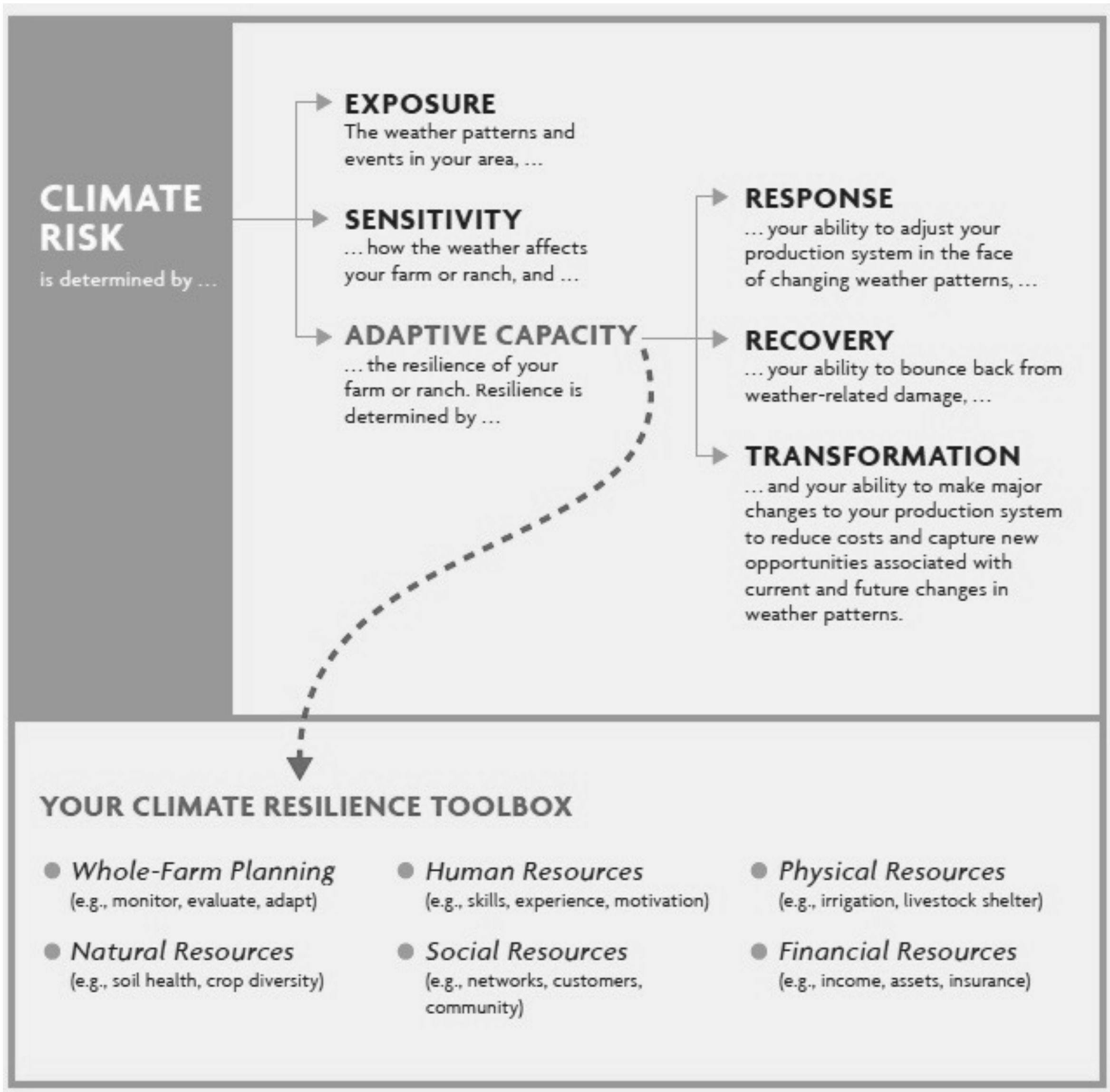

Figure 3. Conceptual framework for understanding climate risk and resilience on farms in the US. Adapted from Lengnick 2018.

2.2.3 Adaptive farm management

Various recent research efforts have documented adaptive farm management strategies in the Northeast, which buffer farms from the risks associated with increasingly variable weather and climate change. General recommendations have been made, based on prior research, as to the effectiveness of conservation practices, such as cover cropping, and riparian buffers, (Janowiak et al., 2016; Tobin et al., 2015; Schattman et al., 2015). Extensive research has also been conducted on the promise of individual management strategies like crop diversification (Lin, 2011) and cover crops (Kaye and Quemada 2017). Crop selection is one management strategy which has been documented across agricultural production types and locations. Crop selection has also been documented as a climate adaptation practice among farmers in South America (Seo and Mendelsohn, 2008), the Canadian prairies (Bradshaw, Dolan and Smit, 20i4), and Bangladesh (Moniruzzaman, 2015). Prior research indicates that crop selection and planning are predicated upon spatial organizing of farmland features into appropriate crop-management blocks (Dury et al., 2013). Although research indicates that cropping patterns have become more specialized since 1994 (Bradshaw, Dolan and Smit, 2014), diversification has been both documented as an adaptation strategy and advocated by experts to manage on-farm risk (Bradshaw, Dolan and Smit, 2014; Schattman et al., 2015). Intercropping and agroforestry systems have exhibited enhanced soil nutrient pools, microbial resilience, and water stress tolerance when compared to control treatments under drought and flooding conditions (Rivest et al., 2013). Soil that has received compost and organic matter additions exhibits increased soil moisture, available P, and plant available N during drought conditions. (Ng et al., 2015). Books authored in the northeast document innovative approaches to climate resilience that are not yet found in scholarly literature, but should be relevant to transdisciplinary research approaches, notably water harvesting and holistic site planning methodologies (e.g. Jacke and Toensmier 2005; Falk 2013; Trought 2015).

Research on adaptive farm management in Northeastern agriculture documents farmers as resilient and adaptive, and identifies strategies which are being employed to manage the risks associated with climate change (Lane et al., 2018; Schattman et al., 2015; Jemison et al., 2014). In Vermont, climate risk management strategies reported at the farm scale include (1) diversification of markets, production, household income and land base, (2) sustainable soil management, including water management in soils, and (3) innovative cropping systems (Schattman et al., 2015). Research by Jemison et al. (2014) in Maine identified over 40 different strategies which farmers are using to manage for climate risks. Importantly, these authors note that climate risk management considerations differ based on operating context, which refers to the combination of site specific characteristics, scale, production type, policy constraints, access to resources, and other pressures which drive decision-making. Recent research on farmers in Pennsylvania and New York (Lane et al., 2018) identify planting dates, changing plant varieties, diversifying crops, installing tile drainage, utilizing cover crops and switching to reduced tillage or no-till practices as the most prevalent adaptive practices in use. Interestingly, research from the Midwest shows a high prevalence of crop insurance as a top strategy for managing the risk of extreme weather (Mase et al., 2017).

The vulnerability and adaptation of agriculture in the Northeast US has received attention from researchers and agricultural support specialists, such as land grant extension program, farmers associations, and the USDA Northeast Climate Hub. However, research on adaptive management in the Northeast has not yet addressed the unique needs of vegetable and berry farmers. The work of experts and scholars to create information on climate change adaptation strategies for agriculture in the Northeast is well captured in recent recommendations from an impact assessment by Wolfe et al., (2018) and the development of a list of potential best management practices from Schattman et al., (2018). Our research is most closely aligned with research conducted by Jemison et al, (2014) which captures the suite of practices farmers consider to be adaptive. The northeast regional climate vulnerability assessment (Tobin et al., 2015) and adaptation workbook (Janowiak et al., 2016) suggest management strategies for vegetable growers, and state specific research has been done on the adapting management of farms in general. However, there is no information on what vegetable and berry farmers are doing or are planning to do (Schattman et al., 2015). Understanding how local agroecological and farm system context influence climate risk management decisions is critical information for technical assistance and other programs that seek to support these farmers in successfully adapting to climate related risks.

2.2.4 Agroecology and resilience

Agroecological perspectives on climate adaptation and resilience in agriculture are limited in temperate climates, though promise to shed light on sustainability within the sphere of climate and agriculture research. Agroecological analysis by Eric Holt-Gimenez (2001) revealed that sustainable farming methods far outperformed conventional farming practices in resisting the impacts of Hurricane Mitch. This study presents the concepts of resistance and resilience as two different properties of agroecosystems, the former being the capacity for the system to resist impacts from natural stressors, whereas resilience is associated with the systems' capacity to recover. Holt-Gimenez (2001) cites Gliessman (1998), Pimm (1984) and Herrick (2000) as sources of this agroecological resilience/resistance theory. The study applies a large set of paired empirical data from

800 farmers through Nicaragua's farmer-to-farmer network. The use of contoured tillage, contoured ditches, terraces and contoured plantings account for functional soil and water conservation through the storm event. Many functional resistance benefits were attributed to cover cropping, integrated pest management, compost additions, reduced inputs, agroforestry, vegetative strips, and alley cropping. The focus on practices in this study found that there are important thresholds in storm intensity and slope at which resistance collapses. Holt-Gimenez (2001) also documented a lag time in economic benefits from agroecological practices.

Altieri and Nichols (2017) suggest looking to resuscitate traditional farming strategies for agroecological resilience, namely biodiversification, soil management and water harvesting. Traditional farming methods have used raised fields to secure production in wet and water-logged soils, as well as furrows and ditches in drylands to capture and hold water in agricultural fields (Altieri & Nichols, 2017). Diversification in crop genetics, and in spatial and temporal heterogeneity, have been observed to increase or maintain the integrity of traditional farming systems through reduced erosion, increased recovery time and enhanced soil health.

Adaptive management practices are not isolated and static. Interactions and functional overlap among practices observed in the Holt-Gimenez study (2001) were also documented in the more recent case study in Canada by Hadartis et al., (2017). Hadartis et al., (2017) noted that some adaptations can set boundaries for others, and investing in one strategy often limits the capacity to change direction in future adaptive management decisions.

It is important to note that adaptive management practices are not all likely to be agroecological practices. For example, Morton et al., (2015) highlight the way tile drainage systems have been used successfully by Midwestern farmers for adapting to water excess, yet this practice has been associated with increasing transfer of nitrates into nearby watersheds (Qui et al., 2011) and falls outside agroecological principles for sustainable agriculture.

Agroecology is a principle-based approach to guiding cropping systems towards sustainability by emulating natural and traditional ecosystem dynamics, minimizing inputs, and increasing ecosystem services (Wezel et al., 2014). Principles of agroecology shed light on strategies for farm scale resilience to climate change that transcend site characteristics and contextual factors, and thus they offer a rubric for communicating and comparing adaptation practices to broader audiences. Scarborough et al. (2014) identified twelve agroecological principles for resilience which can be used as a point of comparison for our study (Table 2). A comparison of how on-farm adaptations reflect these agroecological principles can identify leverage points for communication and innovation, as well as important gaps and resource needs.

Table 2. Agroecological principles for climate resilience. Adapted from Scarborough et al., 2014.

	Preserve and enhance agroecosystem biodiversity
	Enhance soil fertility and nutrient cycling
	Conserve water
	Support ecological pest- and disease- regulating mechanisms
	Minimize use of external synthetic inputs to reduce cost, dependence and harm to agroecosystem

	Manage beneficial ecological relationships
	Maximize renewable energy potential
	Diversify livelihoods to minimize risk exposure to shocks and stresses
	Prioritize and enhance local food security, nutrition and health
	Integrate local and scientific knowledge through appropriate practices and technology
	Strengthen and empower local organizations
	Facilitate shared governance of natural resources

2.2.5 Adaptive capacity

Adaptive capacity, as a function of farmer capability, emerges from the management of basic agricultural asset categories (figure 1). Agricultural management for effective adaptation and mitigation depends on both farmer willingness and capacity to pursue such actions (Howden et al., 2007; McCarl, 2010). The intent to make changes is the last crucial element to adaptation, and for climate-risk management, this poses a unique challenge to agricultural communities within the United States. In developing and developed countries elsewhere in the world, limiting factors are associated with farmers' struggle with capacity, but in the United States, adaptive management can also be limited by climate science skepticism (Chatrchyan et al., 2017).

To support land managers in making adaptive decisions it is important that we consider and develop our understanding of how farmers view climate adaptation measures (Arbuckle et al., 2013). Developing an agroecosystem's capacity to both mitigate and build resilience to climate change requires that farmers have the time and resources to invest in management changes, as well as access to information about the best strategies to employ. The capability of farmers in the Northeast to make change with external forces in mind is a function of available resources combined with the social and ecological factors which influence decision-making. Among the many indicators that researchers have identified, knowledge is an important determinant in adaptive capacity, as are access to financial resources, ecological assets, social networks and physical infrastructure (Williams et al., 2015). Understanding the vulnerability complex and limiting factors for adaptive decision-making through a livelihoods asset framework can help identify key leverage points for intervention and capacity building (Nelson et al., 2010).

Limited research has compared the difference between actual adaptation and planned adaptation (Niles et al., 2016). Those that have conclude that drivers of adaptation behaviors are not universal (Prokopy 2008). One major finding from recent research by Niles et al., (2016) is that beliefs and attitudes are not necessarily associated with behavior change, and this highlights the importance of perceived capacity in motivating adaptation and mitigations behaviors. Niles et al., (2016) suggest "fostering a sense of capacity and confidence" (p 292) as an essential ingredient to enabling agricultural adaptation and resilience.

2.2.6 Research questions:

Our research joins only a handful of studies which explore adaptation and adaptive capacity on farms in the northeastern US (Chatrchyan et al., 2017; Lane et al., 2018; Schattman et al., 2018; Jemison et al., 2014). Where prior research indicates that different contexts and stressors lead to different risk management strategies (Mase et al., 2017; Jemison et al., 2014; Lane et al., 2018), this study directly addresses research gaps by documenting adaptive management uniquely framed for vegetable and berry farmers. It is important to understand the major trends in how extreme weather is increasingly changing agricultural management, and the implications of this for food production, environmental quality and farm viability. It is also important to identify new and promising ideas that can support the increased resilience and sustainability of farms in the region.

This study was embedded within a two-year project which set out to answer this broad question:

- *What information do farmers and outreach professionals need to best support vegetable and berry growers in adapting to the impacts of climate change?*

To this end, this paper seeks to answer the following questions which are a subset of the larger research question:

- *What practices are already in use among diversified vegetable and fruit producers in the northeast to manage for the risks of heavy precipitation and drought?*
- *How are farmers adapting reactively and proactively to account for increasing incidence of heavy precipitation and drought?*
- *What innovative and promising practices are emerging in agricultural networks to adapt to increasingly extreme precipitation patterns?*
- *How do farmers perceive vulnerability and adaptive capacity?*
- *How does adaptation in this community reflect agroecological principles for resilience?*

2.3 Methodology

The goal of this study was to investigate adaptive management strategies, emerging innovative practices and adaptive capacity on vegetable and berry farms in the northeastern US. A survey was conducted in collaboration with eleven farmer networks to gather quantitative and qualitative information from producers across the region. Results from the survey were analyzed and interpreted using a mixed-methods approach.

2.3.1 Field procedure

The New England Adaptation Survey (Appendix A) was developed in fall of 2017 with input from farmers and collaborating farmer networks to optimize the questionnaire's readability, usability and response rate. Researchers referenced five prior surveys on similar themes when writing survey questions. Six farmers trialed the survey and the survey was then revised based on their feedback. Collaborating farmer networks and organizations informed the delivery approach for the survey, resulting in a tailored, mixed-mode survey design (Dillman et al., 2014). Survey responses were solicited in-person at eight farmer network events, and via email through four farmer list-servs between November 2017 and March 2018. The survey instrument contained 77 questions, including both closed and open-ended questions, about: 1) practices already used to manage for drought and extreme precipitation; 2) promising strategies for managing drought and extreme precipitation at multiple scales; 3) perceived barriers and tradeoffs associated with these strategies; 4) in depth information about the of use of cover crops; 5) perceptions of vulnerability and capability; 6) production context; and 7) demographic information. Only a portion of the survey results are reported in this paper. The survey used terminology including “extreme weather”, “risk management”, and “adapting.” The term “climate change” was used at the end of the survey in questions about perceptions. Questions about adaptive management were framed to allow researchers to assess and compare trends in risk management, reactive adaptation, proactive adaptation, and innovative and promising ideas.

2.3.2 Study area and sample

This study was designed to gather information from farmers across northern New England, using a purposeful, convenience sampling approach. We collaborated with eleven farmer networks to solicit survey responses from growers during winter meetings and through list-servs, including the following:

- New England Vegetable and Berry Growers Association (NEVBGA)
- Maine Organic Farmer and Gardener’s Association (MOFGA)
- Vermont Vegetable and Berry Growers Association (VVBGA)
- Northeast Organic Farmers Association New Hampshire (NOFA NH)
- Northeast Organic Farmers Association Vermont (NOFA VT)
- Community Involved in Sustaining Agriculture (CISA)
- New England Fruit and Vegetable Conference
- Northeast Permaculture List-serv
- Rutland Farmer’s Market
- Maine Fruit Growers List
- Rural Vermont

Between November 2017 and April 2018, 193 respondents completed the survey, representing primarily states in the Northeast (Figure 4), plus six responses from Canadian provinces. Basic demographic characteristics of the sample (Table 3), differ from national demographic means. The average age of respondents was 46, positioning the sample as younger than the national average age of farm operators, which was reported as 58.3 in 2012 (USDA NASS, 2012). Our sample also presented itself as more gender balanced than the national statistics for farmers, which was 70% male in 2012 (USDA NASS, 2012), in comparison to 54% for our sample. The majority of the sample is comprised of diversified vegetable farmers and primary decision-makers (Figure 6). Our survey gathered responses from both organic and non-organic growers (Table 3), and represents a well-educated sample of growers, with 75% having attended four years of college and/or graduate school (Figure 7).

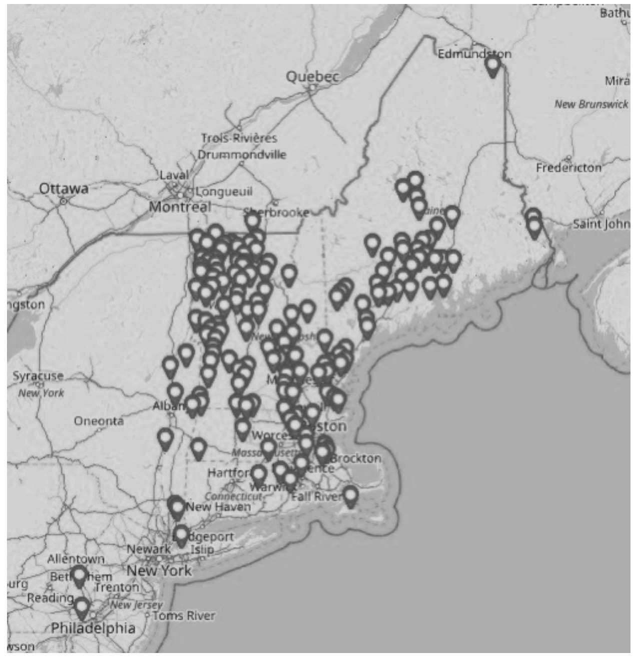

Figure 4. Geographic scope of survey respondents in the northeastern US.

Table 3. Demographics of the sample of farmers who responded to the survey. Total n=193.

Average Age	47
Gender	54% Male, 44% Female, 2% Other
Average total farm acreage in production	27.6 acres

Average years as a decision maker on a farm	13 years
% of participants who grow organic	45%

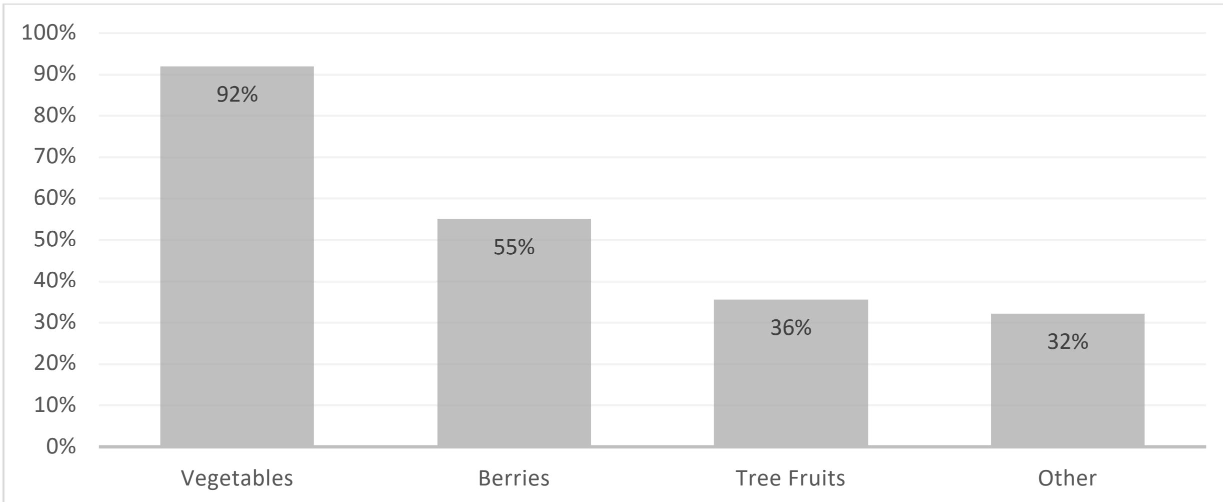

Figure 5. Types of production reported by farmers who took the survey. Many respondents reported more than one type of production on their farm.

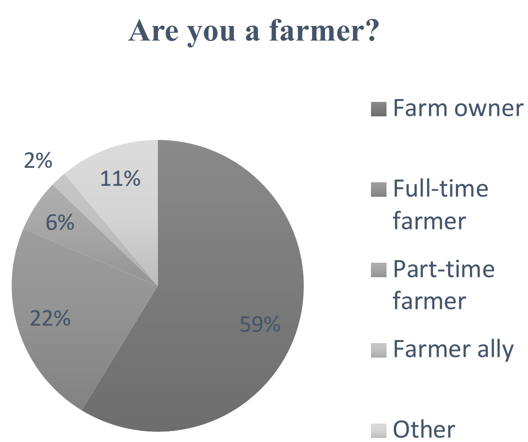

Figure 6. Decision-making roles of respondents.

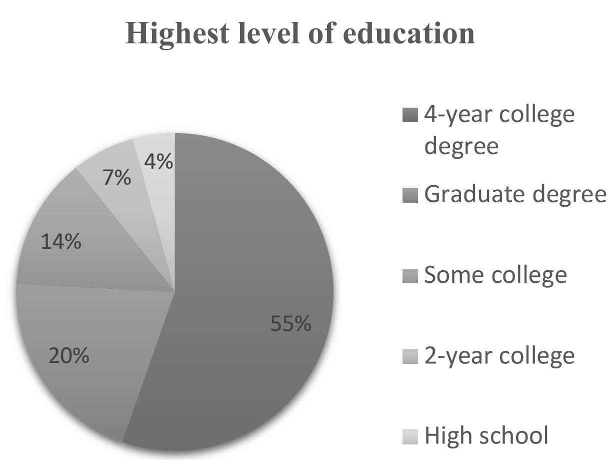

Figure 7. Education level of respondents.

2.3.3 Data analysis

We used a mixed-methods triangulation approach (Figure 8) to bring together complimentary quantitative and qualitative data (Creswell and Plano Clark, 2006). The triangulation approach is one of the most common approaches to using mixed-methods to combine the strengths of quantitative and qualitative data. We collected complementary qualitative and quantitative data simultaneously from the same research subjects in a regional survey. Qualitative data and quantitative data was analyzed separately and then brought together during interpretation. We used themes and patterns from the qualitative analysis to guide the way we present the results.

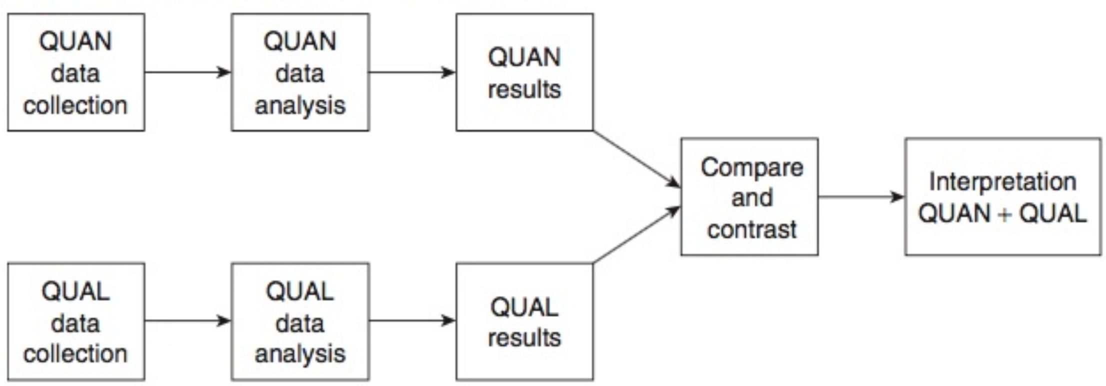

Figure 8. Modified triangulation convergence model. Adapted from Creswell & Plano Clark 2006.

Quantitative data for this study was compiled, sorted and reported as percentages of total responses using Microsoft Excel.

Qualitative data from open-ended questions was analyzed using an inductive approach, guided by open coding methods of grounded theory and constant comparative analysis (Glaser and Strauss 1967; Strauss and Corbin 1990). Constant comparative analysis ensure that categories and theme are anchored by patterns in the data and reflected across the cases through comparing and reading the dataset repeatedly so that thematic categories continually evolve as additional data is collected (Lindloff and Taylor, 2011). Our research team first used open coding to draw out themes and concepts from the dataset (Strauss and Corbin 1990). Further review of the data revealed intensity and recurrence of themes, which were then grouped into a set of evolving axial codes. Keywords and specific phrases were integrated to develop a set of axial codes, which reflected the emergent patterns of categories of meaning. Inter-coder reliability was ensured by coding independently and then cross-checking emerging trends with undergraduate interns who helped to code portions of the data. This coding work was initiated by reading printed copies of the data set, making notes independently and then discussing patterns and trends with the undergraduate research intern team. Comprehensive coding of the large qualitative data set was conducted using NVivo software (Bazeley & Richards, 2000; Gibbs, 2002; Richards, 1999). Grounded codes from this analysis were first published in the report for growers (White et al., 2018).

2.4 Results

We present results in this chapter with a deliberate focus on the adaptive strategies and practices which farmers are using to adapt to precipitation extreme, changes they are planning to make to account for extreme precipitation events, and the innovative and promising strategies that were identified for adapting to extreme weather impacts of climate change. We uncovered some new and emerging ideas from the agricultural community, but for the most part, farmers are making adjustments to established strategies and practices, and building a more holistic perspective on water management across spatial and temporal horizons. Many adaptive management practices are used to adapt to both water deficits and water excess, and some are employed to specifically manage water at one extreme or the other. From the perspective of farmers, adaptive management for precipitation extremes on vegetable and berry farms in the northeast falls mostly within the toolbox of management strategies already in use across the region, although farmers also identified planning, education and mitigation as adaptation strategies.

Respondents reported low levels of perceived adaptive capacity, and a notable concern about climate-related impacts which have a high level of uncertainty. These findings complement our analysis of adaptive management practices to inform the direction of research, outreach and resources for growers.

2.4.1 Trends in adapting to precipitation extremes

Survey participants reported both *having made* changes to their farm management because of an experience with extreme precipitation, and *planning to make* changes to manage for the increased incidence of extreme precipitation patterns. These two frames constitute proactive and reactive adaptive management decisions. Among the participants in our study, reactive adaptive management was more common. Adaptive management decisions based on drought experience were less common than adaptive management decisions based on heavy precipitation. More specifically our data showed that:

- 72% of participants have made changes on their farm because of an experience with, or concern about, heavy precipitation or flooding;
- 61% of participants are planning to make changes that will help manage for the risk of heavy precipitation or flooding;

- 66% of participants have made changes on their farm because of an experience with, or concern about, drought; and
- 39% of participants are planning to make changes that will help manage for the risk of drought.

The responses to open-ended questions in the survey elicited both long and short answers from growers. For instance, when asked about the changes they had made on their farm in response to an experience with drought, some growers would offer short answers such as, “bought more hoses,” while others would list their ideas, “installed a pond to catch water, drilled a new well, installed irrigation (drip to conserve water), started mulching, stopped tilling so much, planting more perennials” or “purchased irrigation equipment, added irrigation work to labor budget, built more greenhouses, reduced vegetable production, started planting summer drought tolerant forage crops.” From this observation, we can see that the extent of adaptive management varies greatly among the sample. Transformational adaptation was rarely mentioned in the survey responses, though one grower reported that they had moved to the northeast from a dry climate so that they could “live in a wetter climate.”

The practices farmers use for adapting to drought and heavy precipitation have some overlap, but also diverge. The strongest themes which emerged from questions about adaptation are listed in Table 4, where we also see some divergence between risk management and adaptation, as well as divergence between changes that farmers made because of an experience with extreme weather (reactive adaptation), planned changes to account for extreme weather (planned adaptation) and the ideas considered most promising and innovative. As a reminder to readers, we asked many questions about adaptation and risk management in order to see these trends. The risk management question represents quantitative data from a multiple-choice question, whereas the other three categories were elicited through open-ended questions and were derived from qualitative data.

Table 4. Trends in adaptive management. The table presented the most abundant themes for each question (those with the highest numbers of mentions) to comparing trends in general risk management with the strongest themes in reactive adaptation, planned adaptation, and innovative and promising ideas elicited from multiple questions about adaptive management in the New England Adaptation Survey.

Trends in adapting to water excess

General Risk Management	Reactive Adaptation	Planned Adaptation	Innovative & Promising Ideas
soil health	raised beds	hoop house or high tunnel	no till
cover crops	site selection	storm water management	cover crop
organic fertilizers	ditching	ditching	crop planning
crop rotation	changed location of crops	perennial plantings	raised beds
green manures	drainage	raised beds	mulch

Trends in adapting to water deficits

General Risk Management	Reactive Adaptation	Planned Adaptation	Innovative & Promising Ideas
soil health	irrigation (general)	updated irrigation	soil building
cover crops	updated irrigation	drip irrigation	mulch
efficient irrigation	drip irrigation	pond	irrigation (general)
organic fertilizers	mulch	mulch	water collection and conservation
crop diversification	wells	rainwater collection	tolerant crops

2.4.2 Strategies for adapting to precipitation extremes

Farmers use many strategies to adapt to the increasing incidence of precipitation extremes on their farms. General strategies used for adapting to both drought and heavy precipitation include soil building, mulch, crop planning, strategic thinking, and controlling water flows across the landscape. Respondents named soil health and soil building strategies foremost for *both* risk management and adaptive management.

Soil health. Soil health was one of the strongest themes that emerged across the dataset. Over 72% of growers reported using soil health as a strategy to manage for the risk of increasingly extreme precipitation patterns. Cover crops were reportedly used by 74% of respondents to manage for the risk of heavy precipitation and by 66% of respondents to manage for the risk of drought. When asked about proactive adaptation, reactive adaptation and innovative and promising strategies, producers mentioned a suite of soil building practices, accompanied by mechanistic understandings of how soil health contributes to resilience.

Growers described that “deep healthy porous soil absorbs, moves and stores water” and that “better quality soil is more resilient.” Specific practices named include cover crops, reduced tillage, and incorporating residues and other organic matter sources. In regards to drought adaptations, soil building was primarily linked to the goal of increasing the natural “water holding capacity of the soil”, whereas “improving drainage” was the goal of soil building for adapting to excess water. “No till system and cover cropping to reduce erosion” were frequently mentioned and considered to be the most innovative and promising strategies for adapting to heavy precipitation. Keyline plowing and subsoiling were also mentioned as practices that increase water infiltration into soil and slow erosion depending on site characteristics.

Mulch. The use of mulch has been employed widely as a reactive adaptation strategy due to experience with both heavy precipitation events and drought. It was also highly mentioned by respondents when asked about planned adaptations, and considered to be promising and innovative by many growers too. Producers named mulch as a strategy to protect soil, such as "more mulches, more protection of soil/cover," and also mentioned specific management practices, such as, "raised bed plasticulture," or in combination with other strategies, such as "increase irrigation capacity + more mulching." Mulch was identified as having many benefits, but most importantly to "prevent erosion" and "reduce evaporation."

Crop planning. Farmers use crop planning as an adaptive management strategy for both increased incidence of drought and increased incidence of heavy precipitation and flooding events. Crop planning includes changes in planting and harvest dates, changes in location of crops, and changes in crop variety or species. Producers noted that they have started to grow more perennial plants, both as primary crops and as perennial borders or buffers around fields. As an example, one grower said, "we changed to perennial plants in flood prone areas instead of annual veggies." Agroforestry was mentioned broadly as a strategy, as well as the inclusion of more trees and deep-rooted perennials. Specific agroforestry cropping systems were also mentioned, such as "intersperse rows of perennial + nursery crops with annuals." Cover crops were an often reported strategy considered by growers in crop planning, used in idle areas, inter-planted among crops and planted to protect soil before and after crops. Growers also reported making multiple plantings, alley cropping, strip cropping, and "planned succession in case of failures."

Many growers have changed the timing and location of some crops due to heavy soils that are prone to staying saturated, or places prone to heavy flooding by "relocating crop rotation elements to keep sensitive crops out of flood prone areas." For example, one grower said they "changed plot layout used to grow vegs to avoid low points in field," while another said they "moved tolerant crops into the wetter areas." Others reported using smaller sized blocks in their plot layout to account for the size of low and waterlogged areas of fields. From general planting date changes, to very precise planting dates based on the locations of beds, growers reported many changes to their cropping calendars. This included later planting dates due to wet soils, cooler wetter weather and flood risk. Many farmers said they were, "planting later in the spring because of cooler and wetter weather" while a few others reported general planting date changes, and even, "planting earlier to take advantage of high soil moisture for critical establishment period." Some crops are also being planted early when grown under protection of hoop houses.

Growers reported changing crops and diversifying crops, and expressed interest in species and cultivars that are more tolerant of extreme weather conditions and excess moisture. Crops that are native, moisture tolerant, and even "suitable for heavy rains" are increasingly considered by growers because these plants could thrive through challenging climate conditions. Some farmers noted that they have reduced crops that, "expose bare ground for too long, such as potatoes," and added crops that consume a lot of water.

Strategic thinking. Some growers stressed the importance of looking at their farm through a holistic, systems level lens, using terms such as regenerative agriculture, agroecology and permaculture. They stressed the importance of "thinking", "rethinking," "being prepared by a long-term policy," and "always looking for better ideas." Specific examples of systems-level changes that came up in the survey responses include using "maps based on flooding," enterprise diversification, measuring water, microgreens production, planting on contour, "using the landscape," and "working with nature as much as possible." In addition to direct mentions of permaculture design, the survey results included the lexicon of ideas popular in permaculture communities, from keyline to hugelkulture, as well as berms, swales and earthworks.

Control and catch water. Respondents reported taking a bigger picture perspective on their farm landscape and water flows with the goal of understanding how to limit erosion and storm water damage, while also making sure that water was conserved and retained on site for times of drought. Farmers reported "diverting water into storage (ponds) for use in later drought." This theme of water harvesting was reiterated across the survey responses, and farmers often identified water management strategies that are similar for both heavy precipitation and drought, such as: "same as heavy precipitation: storm water management, slowing runoff and building sediment catches." One farmer described how they had "installed rain catchment on hoop houses to divert excess water to existing waterways instead of creating new erosional concerns." Many growers reported having invested in passive catchment systems after drought experiences, such as, "rain barrels [and] use of farm pond vs. well." Growers emphasized the importance of paying attention to soils and contours and using them to manage water availability on site. A systems level perspective on how much water is available across the farm benefits both passive water delivery systems and pump powered irrigation systems.

2.4.3 Adapting to drought

When asked about adapting to drought, farmers reported using the general strategies for climate adaptation we have described in the previous sections (soil building, mulch, crop planning, strategic thinking, and controlling water flows across their landscape), but they also described strategies and practices that are unique to adapting to water deficits. These additional strategies employed to adapt to drought include the development of water sources, improvements to water delivery systems, and water conservation. Promising and innovative practices for drought were valued for saving time, increasing water retention, and reducing inputs. Farmers use these adaptive strategies in addition to the general drought risk management practices built into their farm operation (Figure 8), which include mostly building soil health, cover crops, irrigation, organic fertilizers and crop diversification, and rotations.

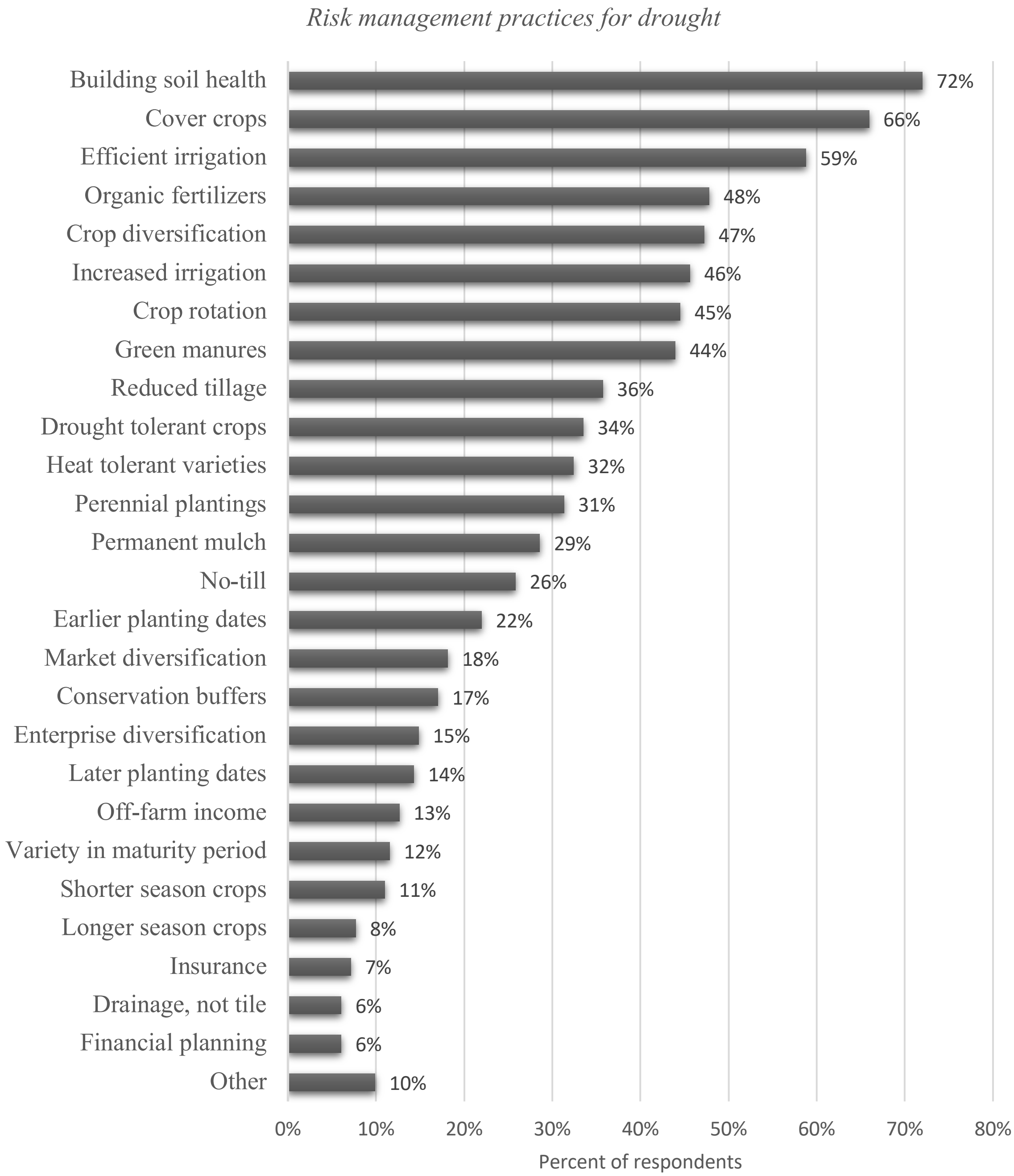

Figure 4. Drought risk management strategies reported by respondents. This figure shows only the quantitative data on general risk management. (Adaptive management practices reported in open-ended questions are not displayed here.)

Improved water delivery systems. New, updated and expanded irrigation systems were the most highly reported strategies for adapting to drought, whereas soil health and cover crops are the most highly reported ongoing risk management strategies (Figure 6). Growers reported investing in new buried mains, valves, timers, more hoses, water reels, and larger capacity equipment, including new well pumps. Drip was the most popular irrigation systems mentioned, but growers also mentioned overhead sprinkler systems, gravity-fed water delivery, and the importance of streamlined systems for time efficiency. Importantly, as one grower described, land tenure was named as a major constraint for growers who wanted to invest in irrigation infrastructure: “I have seen many better irrigation set ups than we have but we are limited because we do not own our land.”

Water source development. Growers reported investing in additional water sources, including additional on-farm wells, “more water storage and collection” and new retention ponds, often mentioned in tandem with other practices, such as “swales + gravity feed irrigation, pond catchment.” Many noted that they have already, or are planning to, invest in infrastructure to access water from existing ponds, nearby springs, rivers and waterways. Growers also reported that they “bought more water tanks”, to increasing their water storage capacity, and placed them in new locations around the farm or near fields. In addition to ponds, water storage containers mentioned by farmers included tanks, 55 gallon drums, bins, and cisterns. Reactive and proactive adaptations included strong themes of, “water catchment and recycling systems” using roofs, gutters, rain barrels, swales, ditches and retention ponds.

Using water wisely: water conservation & drip irrigation. Responses reflect a significant awareness of many ways to conserve water on site or in the soil, from watering during strategic times, to keeping residue on soil surface longer to conserve water in the soil, and using water judiciously. Many people mentioned “spot irrigation” or “drip irrigation” strategies, which use less water, and an interest in buried drip irrigation lines, for overall “better and efficient irrigation.” Growers also expressed an interest in how wash and pack areas could use water more efficiently and recycle water One grower stated “I'm curious of how wash/pack rooms can use H_20 more efficiently or use recycled H_2O.” The creation of shade was an interesting theme that came up to conserve water, both in the practice of setting up large shade cloths over plants, or “keep some trees for shade” in the landscape strategically.

2.4.4 Adapting to heavy precipitation

Farmers have many tools to adapt to the increased incidence of heavy precipitation events, but improving and protecting soil health are the primary strategies that producers use. Practices for adapting to heavy precipitation are attributed to improve drainage, reduce erosion, hold nutrients, save money, allow farmers to access fields earlier, and protect soil. Growers described using the strategies which we reported for general adaptive management (soil building, mulch, crop planning, strategic thinking, and controlling water flows across their landscape) but emphasized the importance of reduced tillage and soil building more so for the risk of excessive water. Farmers described storm water management, site planning, raised beds and hoop houses as having valuable adaptation benefits, which are unique for heavy precipitation events.

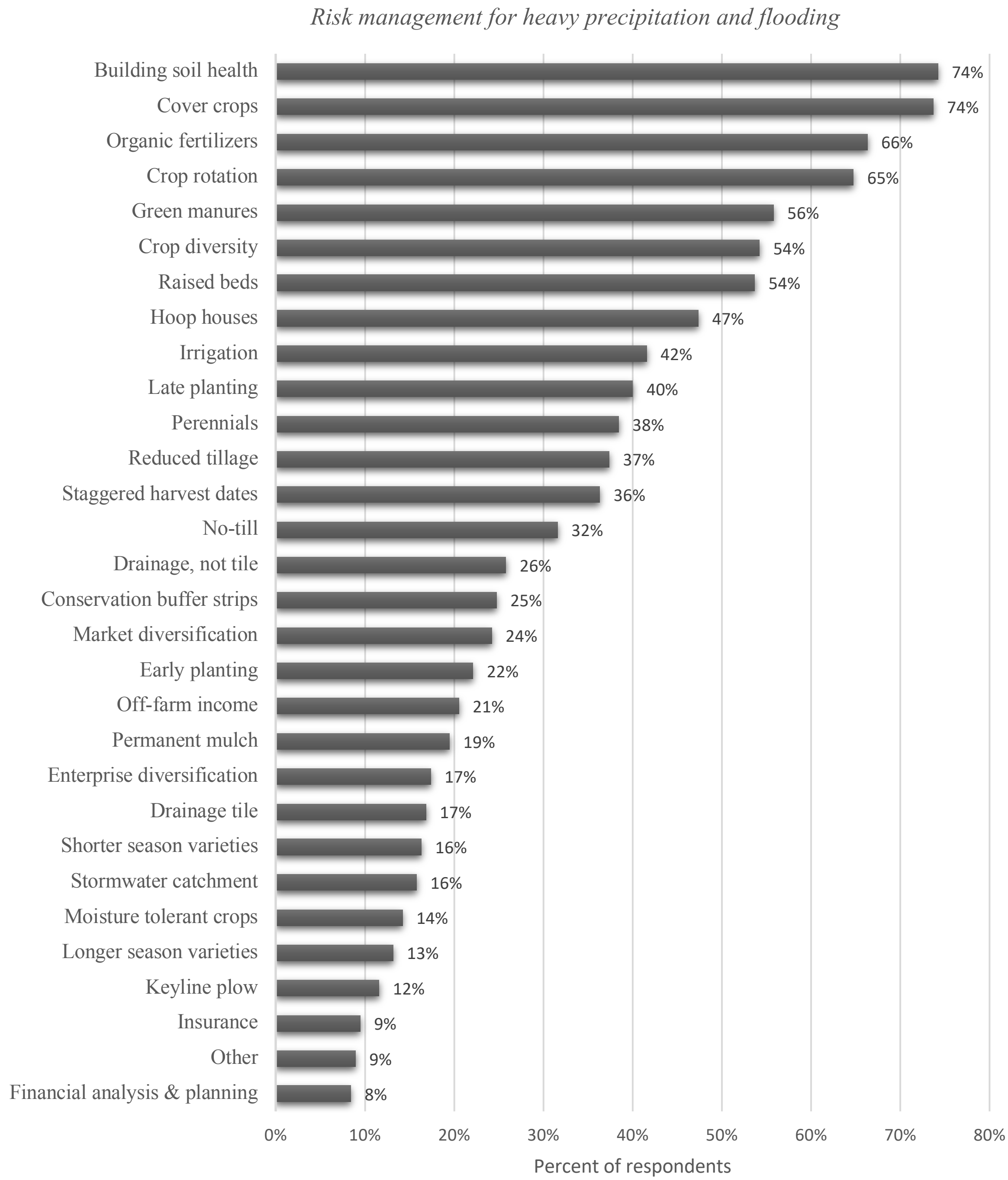

Figure 5. Risk management strategies reported by respondents for heavy precipitation and flooding.

Storm water management. Many survey participants dug new or deepened "more drainage ditches" to control the flow of water across their site, and others simply mentioned "storm water management." Tile drainage was mentioned by many growers as adaptive, and reported to be in use by 17% of respondents (Figure 7). Many associated drainage strategies with downstream watersheds and road or driveway work, like "directing water with road runoff directors." Producers also reported trying increased or new drainage strategies to improve water infiltration and flow through their soils, such as deep tillage or "wheel track subsoiling" to counter soil compaction. Others said they had installed terraces, berms, trenches, "swales, ponds and huglekultures" to slow, control and catch water movement across their landscape.

Site planning for heavy soil and flood risks. Many growers reported paying closer attention to how their site and soil characteristics interacted with heavy precipitation and flooding. Some farmers reported transitioning flood prone fields and heavy soils to perennial plants, pasture, reduced tillage or permanent cover crops. Others reported planting lower value crops, short duration crops or "vegetables that tolerate poor drainage in the sections of our fields that flood." Another grower reported that they stopped cropping in areas of their field, which were poorly drained.

Raised beds. Growers reported "using more raised beds" to adapt to increasing precipitation, often in combination with other strategies or practices, such as, "permanent raised beds with mown walkways" and "raised bed plasticulture." One grower detailed their system for maintaining beds by "building a wheel-hoe with a 12" plow to re-raise beds and shape shoulders by hand-plowing pathways." Raised beds were valued for increasing "drainage," and to "keep water away from roots," as well as "enabling the beds to dry off in a timely manner."

Hoop houses. Growers reported using "more protected culture -- more greenhouses," as well as the, "construction of hoop houses, and caterpillar tunnels," to manage for heavy precipitation events. This practice was not considered adaptive and promising, but came up as a strong theme in questions about reactive and proactive adaptation. Growers described that protected culture and hoop houses allow them the "ability to control moisture" and create conditions for "less disease on plants."

2.4.5 Emerging adaptations

This study gathered responses from farmer networks, which represent ideal places to capture the cusp of innovation and best ideas in adaptive management. We asked farmers to identify strategies they considered innovative and promising for adapting to heavy precipitation, flooding and drought, and the trends in their responses to this prompt included ideas that are both familiar and new. While many of the answers to these questions named strategies and practices that have emerged elsewhere, some of the responses identified strategies and practices which do not appear to have been adopted widely, and thus occupy a unique space in the data set as emerging and promising innovations in adaptive management for vegetable and berry growers.

No-till. Reduced tillage was a strategy that came up across the survey, with no-till emerging as a practice that is considered innovative and promising among many diversified vegetable growers in the community. Adjusting working systems to no-till requires that growers make a major change in production systems, and making this a practice that has not been widely adopted by vegetable growers in the region. Growers recognize the benefits, such as “plants' root system & soil ecology will be better suited to deal w/ drought in no-till” and” increased nutrition and better drainage for clay soils.” Yet, decisions to adopt this practice are limited by perceptions of the large amount of change involved, such as “converting from our current system will be challenging. We have excessively drained sandy loam, so we need to build organic matter for H_20 retention.” And “establishing permanent beds” is challenging in a system that relies on rotation and diversity, and is limiting because it’s a, “whole farm system change,” which makes it, “harder to change land layout once established.”

Hugelkulture. Hugelkulture is a method of burying woody material in raised beds often attributed to Austrian origin. Growers mentioned “building hugel-mounds for water retention in garden” and “planting into hugel mounds to cope with high water table” as adaptive practices for managing heavy precipitation because it “allows young plants to establish without flooded roots and with slowly releasing nutrients.” The practice was also mentioned for adapting to drought. One grower said: “we put in swales, catchment ponds and plant in huglekultures” because it “moves water around, capturing the water and storing it for use and control.”

Agroforestry. Agroforestry concepts emerged mostly as planned adaptations and as an innovative and promising strategy. This included mention of simply, “implementing agroforestry practices” or as “alley cropping,” and in descriptions of “strip cropping,” and “planting more trees” and “hedgerows” Specific management ideas were described, like “lay brush from pruning hardwood canopies along contours,” and “pollarding larger areas--root turnover of hardwoods when pruned increases soil resilience to water logging.”

Keyline. Keyline was an idea that came up as a planned adaptation or a promising idea and is considered by growers to be both a plowing practice and a landscape planning guideline. "Contour/key-line" plowing with a subsoiling implement on contour or slightly off-contour, as well as "keyline planning/diverting water into storage (ponds) for use in later drought," was reported by growers to create a more "even distribution of moisture over the landform," and offers the advantage of being a "passive way to catch, move and distribute water" to "efficiently store water in soils across whole landscapes."

Education as adaptation. Learning and accessing new information are considered innovative and promising adaptive strategies for growers in this community. One grower described the trusted advice from extension agents as the most promising and innovative strategy; "If the drought is consistent, then seeking help from cooperative extension will be the best idea, to help with vegetables varieties that work." From simply "education" and "learning more about soil and water management" and making space for creative problem solving through "more farmer-to-farmer talks about climate change," growers reported a need and desire for more information on how to deal with extreme weather.

Mitigation as adaptation. When asked about adapting to increasingly extreme precipitation patterns associated with climate change models, some farmers mentioned mitigation strategies. Mitigation as adaptive management among vegetable and berry farmers is primarily based on practices that reduce carbon footprint or greenhouse gas emissions. Farm energy sources emerged as important, specifically in producers reporting the use of "more solar panels + hydronic heaters." One grower reported that they "installed solar farm 10 KW," as an adaptive practice. The understanding that farm management decisions have an impact on the drivers of climate change patterns is not lost on this group of growers.

2.4.6 Perceived vulnerability & capability

The majority of farmers in this study reported that they understand the vulnerability of their farmland to the impacts of extreme weather, yet they do not perceive that they have the financial capacity, knowledge or technical skills to effectively deal with those threats (Figure 10). The direct impacts of climate change for the northeast which diversified vegetable farmers are most concerned about are presented in Figure 11, highlighting unpredictable spring temperatures, increased incidence of drought, increased incidence of pest and disease pressures, loss of nutrients, and heat stress as the impacts of highest concern.

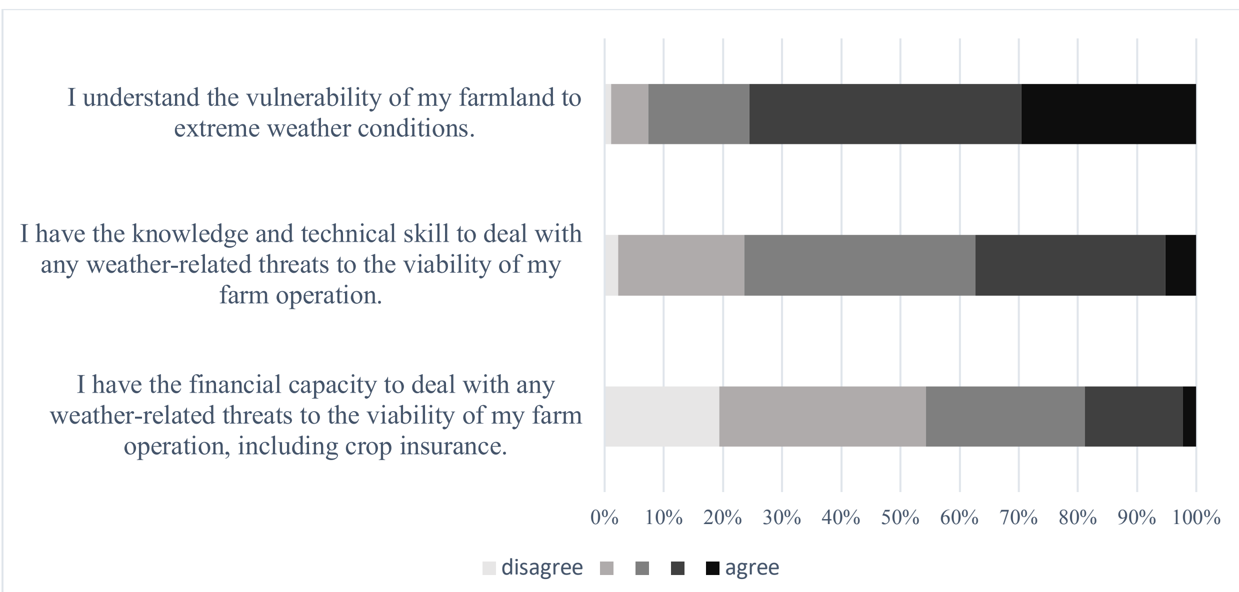

Figure 10. Perceived vulnerability and capability reported by respondents to the New England Adaptation Survey. Participants were directed to indicate their level of agreement with the statement on a scale of 1 to 5.

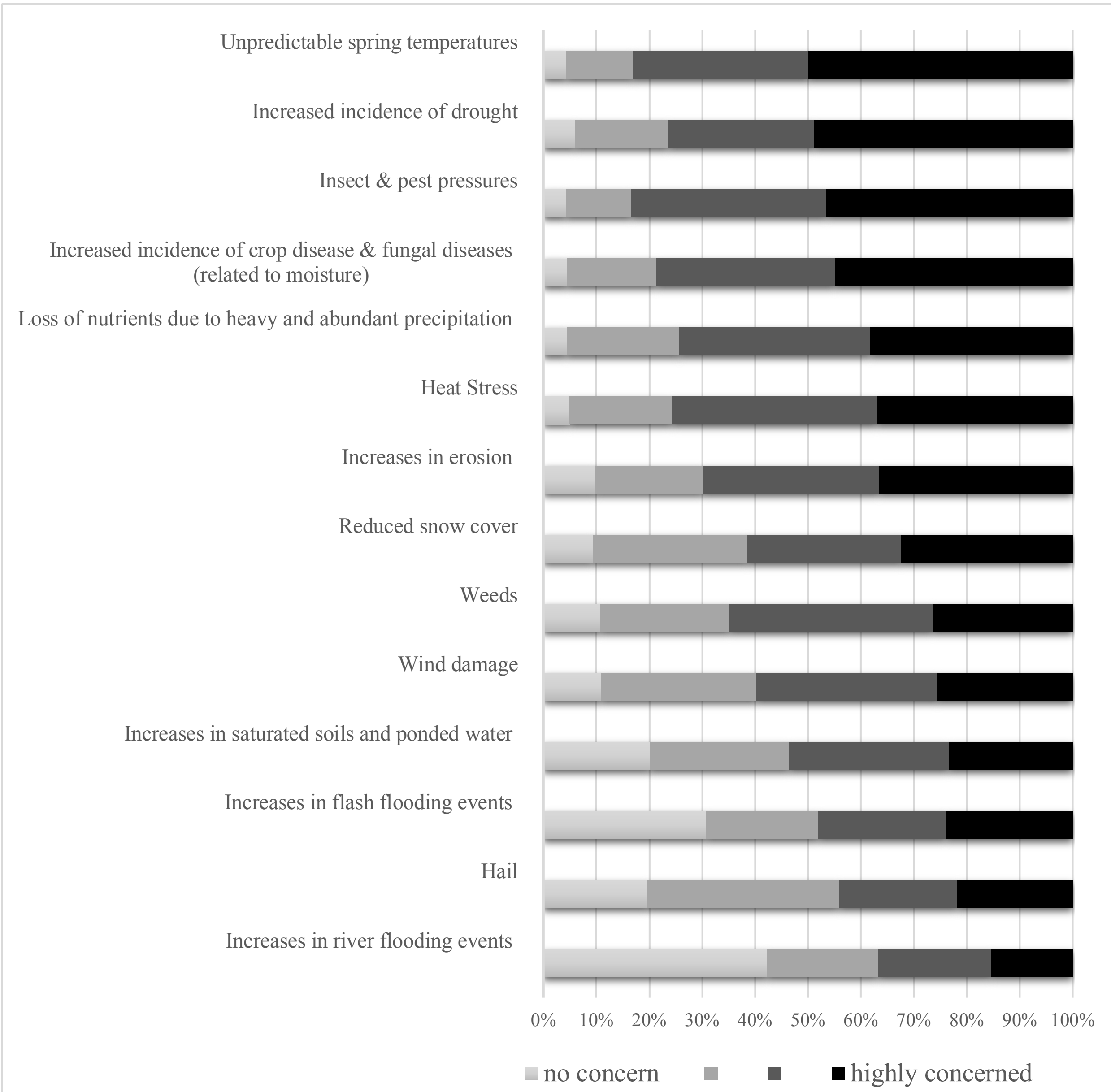

Figure 11. Climate impacts of concern to diversified vegetable growers in the northeastern US.

2.5 Discussion

The results of this study present an enormous amount of farmer knowledge and perceptions about how diversified vegetable farms are adapting to the increased incidence of precipitation extremes projected by climate models for the next century. Much of the findings have transferrable wisdom for other contexts and production sectors. Adaptive management strategies from this community fall mostly into broad categories of soil management, crop planning, controlling water and site planning, but also included mention of education and mitigation as adaptation. The results of this analysis illustrate that vegetable and berry farmers across the northeastern US are concerned about the direct and indirect weather-related impacts of a changing climate.

Strategies and practices documented in this study concur with aspects of many prior assessments and recommendations for agricultural adaptation, though our study reveals some divergence, new trends and promising practices that are unique to this community of diversified vegetable and berry farmers.

2.5.1 Theoretical implications

Farmers reported investing primarily in capacity to respond and recover from weather extremes, and transformational capacity was rarely mentioned. Our study documents farmers investing heavily in physical resources (such as hoop houses or irrigation equipment) and natural resources (such as soil health and plant genetics), which support their capacity to respond and recover from precipitation extremes. Strategies like water harvesting represent investments in natural resources that fall under Lengnick's definition of transformative capacity.

Our findings also document farmers' adaptive management decisions to be primarily incremental, and rarely transitional in the sense intended by Park et al., (2012) and Pelling (2010). Farmers in this study saw adaptations as tools that will modify their established system to continue to meet their farm's goals, reduce risk, and sometimes take advantage of extreme conditions. System level transformation was rarely mentioned, and transitional adaptation, or more significant incremental adaptations remained primarily in the promising or innovative category. As an example, no-till constitutes an emerging strategy, which requires significant system-level changes but retains the same farm production goals. This strategy was considered, but noted to have drawbacks, for systemic change. Only one true transformation was described, and that was the grower who had moved 3,000 miles to a more hospitable climate. Lengnick's (2018) interpretation of resilience theory and transformation is more useful for interpreting adaptation and resilience at the farm-level context, which emphasizes the way farmers might invest in the capacity to transform climate impacts and either take advantage of them (like water harvesting) or the capacity to change their farm system (such as diversification in production type).

For farmers who invest in the capacity to withstand and absorb the impact of increasingly extreme precipitation, the foreseeable changes to their livelihood are relatively small. For those farmers who invest in a transformative capacity, they will also require additional human capital, skills and lifestyle changes. Incremental adaptations often represent the low hanging fruit, which require smaller investments. In contrast, transformational adaptation often requires large resource investments and thus leave them significantly more vulnerable/less capable for the next stress/shock.

Our findings enrich scholarship on agroecological strategies and principles for resilience. Strategies used by diversified vegetable famers in the northeast align with the traditional agricultural wisdom captured by Altieri and Nichols (2017) in the use of soil building, biodiversification and water harvesting. Our findings add to the toolbox of agroecological adaptations that both reflect ecological principles and enhance farm resilience. Six of the agroecological principles for resilience from Scarborough et al., (2014) are represented in the adaptations named by farmers in our study. In table 3 we organize these principles and corresponding strategies and practices which emerged from the dataset.

Table 5. Adaptive management practices and strategies which emerged in our study align with agroecological principles for resilience.

Agroecological Principles for Resilience	Strategies	Practices
Enhance soil fertility and nutrient cycling	Increased vegetation & roots, increase organic matter	Cover cropping, hedgerows, agroforestry, compost additions
Conserve water & soil	Reduced tillage, mulch, water catchment, water conservation	No-till, cover cropping, green manures, mulch, conservation irrigation
Maximize renewable energy potential	Use solar energy	Solar panels
Minimize use of external synthetic inputs to reduce cost, dependence and harm to agroecosystem	Organic fertilizers, reuse materials, reduce inputs	Cover crops, green manures, water conservation, water catchment
Preserve and enhance agroecosystem biodiversity	Crop diversification, buffer plantings	Agroforestry, native plants, seed saving
Integrate local and scientific knowledge through appropriate practices and technology	Peer learning networks, farmer-advisor partnerships	On-farm consultations, on-farm research, farmer-to-farmer workshops

2.5.2 Practical implications

The diversity of crop and soil management strategies reported by farmers in this study illustrates that farmers in the region are actively adapting to climate-related risks and have many options for managing extreme weather risks on their farms. Our study documents practices which farmers perceive to be effective in helping them adapt to precipitation extremes associated with climate change projections, yet it does not assess if they are truly effective. Yearly and seasonal crop planning is characteristic of vegetable production systems because crops are primarily annuals, and this affords a good opportunity for farmers to incorporate climate risk management in their decision-making. The reported soil health management strategies have many other benefits and advantages to agricultural production and ecosystem health, beyond managing for heavy precipitation, which likely contribute to their high levels of reported use. Research has established that building soil health and using cover crops have multiple benefits for farm businesses and ecosystem health. Importantly, these adaptive practices also influence human induced forcings by increasing albedo and reducing net CO2 emissions (Kaye and Quemada 2017), and offer the possibility that adaptations on farms can be coupled with efforts to mitigate human-induced climate changes.

Our study reveals that reactive adaptation is more common that proactive adaptation on farms in the northeast. This is corroborated by other research, which concluded that previous experience with extreme weather is a major driver of risk management behaviors (Schattman et al., 2016). The implications of this finding mean that without support from advisors and resource providers, farms are likely to suffer significant losses before they invest in the capacity to withstand impacts of extreme precipitation on their own. This also means that when the impacts of extreme weather occur with a force that has yet to be seen by farms in the region, as is projected by climate models, the results are likely to be catastrophic for farms and livelihoods.

Our research does not investigate why proactive adaptation is less common, but outreach and resources for adaptive management and adaptive planning are limited and emerging in this community. Just in the last few years, we have observed new programs on the topic from some farmer networks, as well as the creation of new documents and resources from the USDA Northeast Climate Hub. It is our sense that this conversation is picking up and many networks are just figuring out how to talk about it. Given the dearth of outreach and resources for farmers, on what proactive adaptation looks like, information on adaptation could be useful. Farmers in our study reported investing in knowledge through planning and education as adaptive, and that is a unique and important contribution from our findings, specifically calling for more extension agents to support farmers as they plan for climatic changes.

Our study highlights that despite a wealth of knowledge and ideas about adaptation, the perceived capacity to adapt within this community of growers is quite low. Given Niles et al., (2016) emphasis on perceived capacity as an important driver of adaptation behavior, more research is needed to identify the resource gaps and essential points of intervention for capacity building in this community. Comparing the way farmers have adapted to the recommendations of experts offers significant insight into needed technical assistance and research. Some strategies that were reported in low use, such as conservation buffer strips, are widely recognized as best practices for climate resilience (Schattman et al., 2016). Further research is needed to identify why the adoption of such practices is low, and address barriers. Understanding the gap between implemented and desired adaptive management strategies offers critical information for policy makers and technical advisors who seek to support farmers in adapting to climate change, and although our study identified some of the rationale for this, more research is needed on the topic.

Risk concerns of farmers who participated in this study were highest among the indirect and nuanced ecological and environmental projections of increased incidence in moisture-related diseases and nutrient losses in soils due to increased precipitation. This points to an important nexus of where farmer management concerns overlap with impacts of climate change. This has implications for how research and outreach should be framed, as well as what research land grant institutions should be pursuing to best serve agricultural communities. Nutrient leaching and how soil management strategies impact nitrogen availability to crops is poorly understood by growers in Vermont (Becky Maden, personal communication), and is of high concern to growers. Further analysis and research is needed to better understand how local farmers perspectives' influence their adaptive management decisions to help tailor the delivery of outreach materials to agricultural audiences.

This study also adds new ideas to the empirical research on agricultural adaptation to climate change in the US by documenting mitigation as adaptive, the low use of financial strategies, and extensive site planning as important strategies. Crop insurance is an important risk management strategy utilized by growers in other agricultural sectors, but our study reveals that farmers in the vegetable and berry sector have not invested in financial resources and safety nets to protect them from extreme precipitation events. Catastrophic losses due to extreme weather events are likely to occur and have significant impacts on farm viability due to crop losses and infrastructure damage. Financial safety nets for vegetable and berry growers in the northeast constitute an important resource gap. Emergency relief funds have emerged in recent years in response to catastrophic losses experienced by farms due to extreme weather. This illustrates the importance of structural and community-based support mechanisms to complement individual scale adaptive capacity. Assessing the interplay between structural/community scale resources and individual scale resources for resilience could require novel research methods, but would offer a more comprehensive perspective on adaptive capacity, and resource gaps.

Farmers in our study reported low use of crop insurance (less than 8%), and low use of financial planning (less than 10%). This diverges from other studies of US farmers most notably in the low adoption of crop insurance, which Mase et al., (2017) describe as a primary adaptive strategy used among US corn farmers in the Midwestern US. Mase et al., (2017) showed that 59% of farmers in their study reported purchasing additional crop insurance as a weather or climate risk management strategy. The failure of crop insurance to support these growers is important, and indicates that relying on research from corn country to assess the needs of all growers in the US will leave some sectors unsupported. Financial planning is important for farmers in the region, who will likely experience major losses due to extreme weather. This represents a major opportunity for programming and resources geared toward this community.

Much of the research on adaptation in the US has focused on the role of perceptions and norms in driving behavior, with implications for resilience, but this research does not capture the opportunities and spaces for normative shifts that would inspire effective changes. It is important to note that from a participant observer perspective, farmers were eager to learn from their peers through the survey results. The action research part of this project was important because although much research points to the importance of perception and belief in driving adaptation behaviors, perceptions and beliefs can change. That is why the learning and educational aspects of participatory research are so important to this project. Engaging stakeholders in the research process increases opportunities for learning from multiple stakeholders.

For most of the practices reported in this study, adaptive management represents changes that make farms more sustainable. However, some drainage strategies, such as tile drainage and ditches that divert water directly into nearby waterways neither fall into the BMPs identified in prior research (Schattman et al., 2018), nor do they reflect agroecological principles for climate resilience (Scarborough et al., 2014). This type of management is adaptive, in that it buffers farm productivity from water logged soils and the risks associated with increasingly heavy precipitation events. Importantly, it reduces the water purification ecosystem service of a farm, and can negatively impact downstream ecosystem health and community. Without guidance from advisors or policy, agricultural management practices that confer negative environmental externalities are likely to remain in the adaptation toolbox of growers.

2.5.3 Limitations

Farmers may not have mentioned some strategies because our survey instrument did not elicit them. For example, we know that some farmers in Vermont have been supported by emergency farm funds after extreme weather conditions, but this did not come up in the survey. The majority of answers to open-ended questions in the survey constitute field scale farm management strategies and practices, and this may be because this is the first place that farmers look to control the immediate outcome of weather impacts on their farmland. Farmers may have also utilized financial resources and human capital development to respond and prepare for increasingly extreme weather, but did not report it.

Another limitation of the study is the sample, which was a purposeful convenience sample. We did not gather the perspectives of all growers, nor did we access all networks. Thus our survey does not represent an exhaustive review of adaptation in the region. Our sampling method has drawbacks, but we believe it allowed us to capture an excellent picture of adaptation on farms in the region.

And finally, our focus on precipitation extremes as climate impacts of high concern is useful for organizing and communicating adaptation, but does not offer a complete picture of adaptation to climate change. Further research on how these growers are adapting management to account for changing spring temperature patterns, and increasing pest and disease pressures are important to give a complete perspective on climate change adaptation.

2.5.4 Future Research

The results of this study can help prioritize interventions and identify research needs to match the emerging adaptive management strategies of farmers in the region. The efficacy of the strategies that farmers are using to adapt should be assessed in partnership with research professionals. Most importantly, a thorough assessment of existing resources that support the adaptive capacity of farmers, at multiple scales, should highlight the way individual level and community scale resources complement each other. In addition, it could identify the most important gaps and leverage points for programs and information to build agricultural resilience to climate change in the region.

Finally, further analysis and research is needed to better understand how local farmers' perspectives influence their adaptive management decisions, and would help tailor the delivery of outreach materials to agricultural audiences.

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CHAPTER 3: THE INFLUENCE OF SITE CHARACTERISTICS ON ADAPTIVE MANAGEMENT STRATEGIES

3.1 Abstract

In this chapter, I examine the way site characteristics impact adaptive management practices. The chapter begins with a review of literature that highlight the importance of site characteristics in driving agricultural decisions, and the way climate change intensifies the vulnerability of some sites. Themes that emerged from our analysis of open-ended survey responses highlight the importance of site characteristics in driving the management strategies and practices which farmers use on their fields. Our analysis triangulates these farmer perspectives with regression modeling of quantitative data which correlates adaptive management practices with site conditions. The variables used in this study include basic soil types (sand silt, clay and loam), common geologic features within soil profiles (gravel or ledge), and three landscape characteristics which determine exposure to extreme weather impacts (flood plain, steep slopes and windy sites). The results of our study indicate that farmers consider their unique site and soil characteristics when making adaptive decisions. Some practices evaluated in our study are strongly tied to site and soil characteristics, whereas other practices, like green manures, are utilized to adapt to increasing precipitation extremes regardless of site characteristics. Practices which were highly correlated with soil and site characteristics include the use of conservation irrigation on sandy soils, the use of perennial plantings and permanent mulch on steep slopes, and the use raised beds on clay soils and steep slopes.

3.2 Introduction

Traditional farming practices, existing scientific literature, and local farming knowledge points to the importance of site characteristics and soil properties in driving appropriate land management strategies. In agricultural landscapes, slope, soil type and aspect can constrain the type of production or plant selection which will be successful, economical or ecologically sustainable on a given site. Exposure to extreme weather can heighten the site-specific vulnerabilities of farms, and the trend in increasing precipitation extremes which farmers have experienced is projected to increase by climate models. Adaptive management for extreme weather will likely reflect site characteristics, and be driven by unique soil and landform features that interact with weather extremes. Importantly, farmers and advisors will need to direct more attention to the implications of enhanced site vulnerabilities on farms due to climate change.

Place-based traditional agricultural practices reflect this grounded wisdom outside the realm of scientific research. In the Mayan agricultural tradition, terraces have been used to conserve soil and water in steep and mountainous regions for centuries (Beach et al., 2002), and this wisdom is reflected in traditional agriculture in Asia and Africa as well (Lal, 2008). Traditional agriculture in Africa, Central and South America have also used water management principles to interface agriculture with wetlands and saturated soils through the use of raised beds, ridging, mounds (Lal, 2008; Gale et al., 1993).

Leading agroecologists identify the combination of site and climate as defining characteristics that limit and drive ecological potential and expression of agriculture in any agroecosystem. Gleissman (2006) refers to this in defining "the environmental complex," whereas Rice and Vandermeer (1990) draws from the field of agroclimatology, which is dedicated to describing the way climate and landform interact to define agriculture appropriate to a given place or region. Rice & Vandermeer (1990) observe that, "in conjunction with natural vegetation, parent material, terrain and time, climate produced a particular soil in a particular place… [and] certain soils are conducive to particular crops and cropping systems" (p.22), attributing this wisdom to millennia of experience of agriculturalists. Altieri et al., (2015) also looks to traditional farming methods to link site characteristics to suitable practices, and recently reviewed the utility of modeling this place-based wisdom to guide the development of climate resilient agriculture. Altieri et al. (2015) call for a suite of agroecological strategies that reduce vulnerabilities to climate, including "crop diversification, maintaining local genetic, diversity, animal integration, soil organic management, water conservation and harvesting" (p 869), highlighting the ancient raised bed systems used in the Andes on sites that experience seasonal flooding to both reduce the impact of excess water and saturated soils on crops and to ensure that moisture is available during times of drought. Crop diversity is suggested as a broad strategy that traditional farmers have used regardless of site conditions to buffer the impacts of climate variability. Holt-Gimenez (2002) documented the use of many sustainable farming practices in central America, such as agroforestry, contour farming, cover crops, etc. to significantly limit erosion and mudslides which occurred due to Hurricane Mitch. This study represents one of the most referenced empirical data sets that measures agroecological resilience to the extreme weather associated with a changing climate.

While many efforts have been dedicated to chronicling the localized agricultural knowledge of traditional farming cultures, far less agricultural anthropology documents the way site conditions have influenced modern agriculture in the US, though site conditions are often essential to the way farmers communicate and compare practices (Wood et al., 2014b). Wood et al., (2014b) describe how farmers focus on the details of contextual differences and similarities on-site, in order to discern what they know about management and how it can be applied to their own farm. Much of the rationale behind the way site characteristics drive appropriate agricultural land management has been picked up and utilized by precision-agriculture advocates, for use in modelling water needs (Fountas et al., 2006; Aubert et al., 2012; Dury et al., 2012), and from this we can glean that soil characteristics and landform influence water availability and spatial patterns and features are important to driving recommended land use and agricultural management. This is also true of conservation efforts and tools, that use related landscape characteristics to risk of soil erosion, runoff, etc.

3.2.1 Study Context: Exposure and Sensitivity on Northeastern Vegetable and Berry Farms

Agriculture in the Northeast has a high level of exposure to extreme and heavy precipitation events. Historic trends show that the region has already experienced a 71% increase in very heavy precipitation events since 1958 (Kunkel et al., 2013). Projections suggest increasingly frequent flooding (Kunkel et al., 2013), as well as increasingly heavy downpours and extended periods of rainfall through the coming century (Wolfe et al., 2018; Melillo et al., 2014). Some of the most agriculturally productive soils are in the floodplain, and the increase in heavy rain events could also mean an increase in flooding events on farms in the floodplain.

Accurate and downscaled climate information models presented for the impacts of concern to local communities make climate information more useable (Li et al., 2018). The most recent downscaled vulnerability and agricultural impact assessment for the Northeast by Wolfe et al., (2018) projects that under the "business as usual" emissions scenario (RCP 8.5) the frequency of rainfall events greater than 5 cm will increase by 50 and 75% between 2040- 2069, and double by the end of the century. Precipitation events greater than 10 cm are projected to double and triple in frequency along much of the Northeast by the end of the century. Seasonal precipitation patterns which emerge from this modeling work indicate that most of the increased precipitation will occur in winter and spring months. Novel water deficits and periods of summer drought are also projected to increase in the region due to increased potential evapotranspiration and stagnant or declining precipitation occurrence during summer months (Wolfe et al., 2018). Of importance, these downscaled projections by Wolfe et al., (2018) indicate that alternate carbon pathway scenarios with reduced anthropogenic contributions to atmospheric CO2 would reduce the projected catastrophic level impacts on agriculture. Although, even the most optimistic RCP projects that extreme precipitation events will increase for the region.

These risks are shared by growers across the region, but the unique characteristics of each agroecosystem will influence the individual sensitivity of a site to extreme weather impacts, and climate change will exacerbate the way site conditions define sensitivity to climatic conditions. Agricultural production in the Northeast occurs in varied soils and sites, from steep rocky slopes to rich river floodplains, thus offering a unique context to compare how management strategies differ by site characteristic, especially those that are used by growers to adapt to climatic changes.

The intense crop and soil management which characterizes diversified fruit and vegetable farmers make them particularly sensitive to extreme precipitation patterns (Walthall et al., 2012). Soil in annual vegetable production systems is commonly disturbed frequently throughout a single season for purposes of soil building, bed preparation, and crop turnover. Many farmers also till or hoe soils consistently through the season to control weeds. This strategy is particularly prevalent among organic farmers, who employ this strategy in the stead of chemical weed controls (Schonbeck 2010). These activities leave soils uncovered and disturbed, where rain and runoff can erode soil and damages soil structure. Some of the most agriculturally productive soils are in the floodplain, and the increase in heavy rain events could also mean an increase in flooding events on farms in the floodplain.

3.2.2 Erosion & Site Characteristics

Erosion is recognized as a driver of land use changes, and constitutes a major concern for growers and soil conservationists (Bakker et al., 2004). Together the changing rainfall patterns, wind patterns, and land use patterns driven by climate change interact with existing soil characteristics to drive increased erosion (figure 1; Valentin, 1996). Soil erosion rates are influenced by slope, soil grain size, bulk density, surface roughness, runoff length, velocity, shear stress of overland flows, and the friction coefficient of soils (Liu et al., 2001). Climatic changes will influence soil erosion directly through changes in wind and rainfall, and indirectly through changes in surface cover and vegetation (Valentin, 1996: p 317). Wind erosion rates increase significantly for bare soil, and even more so when bare soil is dry (Valentin 1996). Increasing incidence of drought will reduce vegetative cover, which exacerbates erosion from wind and water (Rosenzweig et al., 2001).

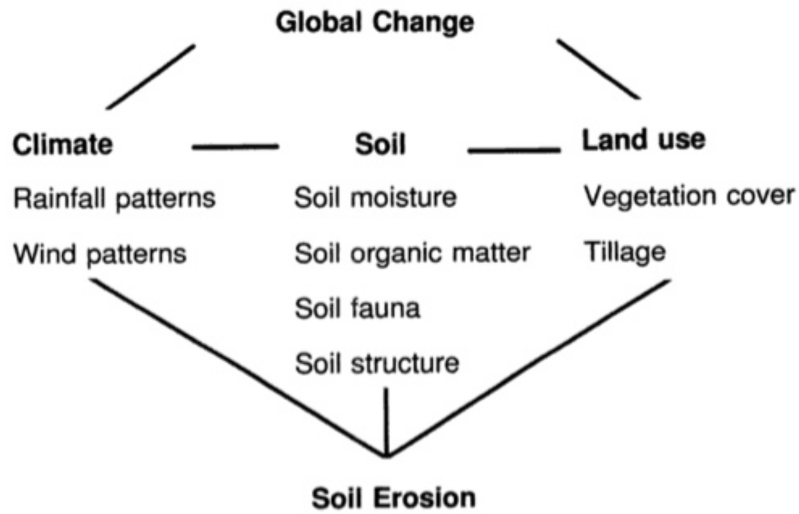

Figure 6. Main factors of soil erosion under climate change. Adapted from Valentin, 1996.

Erosion is important for many reasons, but in the context of agriculture, soil conservation ensures the long-term sustainability of farm productivity by protecting soil health, and limits negative impacts to watersheds downstream from increased particulate matter and nutrient or pesticide pollution to downstream watersheds (Lal, 2012). Traditional, agroecological, sustainable and conservation farming practices typically aim to reduce or eliminate erosion for both of these on-site and off-site reasons. As soil scientist Rattan Lal explains;

> ”The on-site adverse effects of severe erosion are due to loss of the effective rooting depth, reduction in plant-AWC, depletion of SOC and plant nutrients, decline in soil structure, and reduction in soil quality. The off-site effects of erosion are caused by run-on and inundation, sedimentation, non-point source pollution, and emission of greenhouse gases (GHGs) into the atmosphere. The agronomic, economic, and environmental effects of accelerated erosion are colossal at regional and global scales.” (Lal 2012)

Soil type and characteristics are an important baseline driver of cropping decisions and cropping plans (Dury et al., 2012). Saturated soils are significantly associated with the increased use of drainage strategies, and reduced usage of no-till, cover crops, and planting on steep or highly erodible land (Morton et al., 2015). Soil type and characteristics interact with land use and climate to define erosion impacts (Valentin, 1996; Lal, 2012).

Much of the most agriculturally productive soils in the Northeastern US are in floodplains and constitute and important site characteristic that may have unique cropping and soil conservation trends. Farming in the floodplain offers growers highly productive soils, that are often renewed periodically via soil deposition, though the risk of periodic flooding events that damage crops is expected in these sites. The projected increases in heavy rain, and thus flooding events heightens the vulnerability of this agricultural context to extreme weather by threatening both increased frequency and intensity of damaging flood events. This is important to growers because it risks direct damage to crops and infrastructure, but also increases the potential to experience post-flood syndrome. Post flood syndrome manifests in crops typically the year following a flood event, by causing reduced P uptake due to limited arbuscular fungi (Ellis 1998) and limiting plant growth and productivity.

3.2.3 Decision Making

Site and soil characteristics constitute important biophysical constraints and opportunities for land use and agricultural activity on a site, though they are not the only driver of decision-making for farmers. In the context of climatic change, farmers' decisions regarding adaptive management depend upon both farmer willingness and capacity to pursue such actions (Howden et al., 2007; McCarl 2010). Willingness to adopt is influenced by perceptions of complexity, advantages, and compatibility, along with social influences in the context of external culture and policy (Wejnert 2002). Our study seeks to highlight site and soil characteristics as important baseline biophysical factors that influence adaptive management.

3.2.4 Research Prompt

Traditional farming practices, existing scientific literature, and common farming knowledge points to the importance of site characteristics and soil properties in driving appropriate land management strategies. In agricultural landscapes slope, soil type and aspect can constrain the type of production or plant selection which will be successful, economical or ecologically sustainable on a given site. Exposure to extreme weather can heighten the site-specific vulnerabilities of farms, and the trend in increasing precipitation extremes which farmers have experienced and is projected to increase by climate models. Adaptive management for extreme weather will likely reflect site characteristics, and be driven by unique soil and landform features that interact with weather extremes. Importantly, farmers and advisors will need to direct more attention to the implications of enhanced site vulnerabilities on farms due to climate change. From the perspective of resource and outreach professionals who aim to support farmers in adapting to climate change, soil type and site characteristics are often key factors that influence decision making for farmers, so framing adaptation options through this lens will be more useful to growers.

We find little literature that examines site characteristics in the context of adaptation to climate change, and none that evaluate this in the northeastern US, though recent regional research on adaptation using farmers voices has pointed to the importance of context in driving adaptation decision-making (Lane et al., 2017; Jemison et al., 2014). Notably, “farmers indicated a need for more site-specific and production-specific information on how the climate was going to change over time, which could help them adapt to these climate and microclimate impacts” (Lane et al., 2018). Our paper joins these two studies in documenting adaptation in practice through the voices of farmers in the northeastern US, and offers additional downscaling of context by focusing on the unique experience of vegetable and berry growers.

With this in mind, we sought to answer these questions:

- *Do adaptive management strategies differ based on the site-specific vulnerabilities of farms?*
- *How do soil and site characteristics influence adaptive management strategies?*

3.3 Methods

3.3.1 Study Design

This paper is based on results a survey completed by 193 farmers in the Northeastern US on the topic of climate change adaptation called the New England Adaptation Survey (White et al., 2018). Drawing on the results of the New England Adaptation Survey (White et al., 2018), we use a mixed-methods convergent triangulation approach (Creswell and Plano Clark, 2006) to compare complimentary qualitative and quantitative data on how site characteristics influence adaptive management. This approach allows the research team to analyze data sets from the same sample separately and then integrate them during interpretation of the results. We first present direct quotes from farmers about how site characteristics influence management decisions. Regression analysis allows of quantitative data then presents statistically robust odds ratios linking site characteristics and adaptive management.

3.3.2 Qualitative data analysis and the chain of reasoning

Using inductive and then deductive coding, the qualitative data set was coded for reference to site characteristics. The author recognizes the cycle of inductive and deductive reasoning as having been described by mixed methods scholars as the chain of reasoning (Krathwohl, 2004) the cycle of scientific methodology (Tashakkori & Teddlie, 1998) and the research wheel (Johnson & Christiansen, 2004). Our study represents a mix of inductive and deductive reasoning, and as a broader approach follows a confirmatory path from theory to data to description (Johnson & Christiansen, 2004). In this study, the idea that site characteristics drive management was conceived as a theory, based on our experience in farming, before the survey was designed. The survey instrument was designed to test this theory using quantitative data. Qualitative data emerged to support the theory from the open-ended questions elsewhere in the survey. This occurred when the data was coded for emergent themes, guided by grounded theory, as described earlier in Chapter 2 of this thesis. Deeper deductive coding, specifically for site characteristics, was conducted at a later stage specifically to complement our quantitative analysis linking soil and site characteristics to adaptive management.

3.3.3 Treatment of the quantitative data

Using data collected in a survey of 193 diversified vegetable and berry farmers across the Northeastern US between November 2017 and April 2018, we use a regression modeling approach to identify the links between site characteristics and adaptive management practices. Binomial logistic regression models, often referred to as "logit models," have been widely used to assess influences on the adoption of land management practices in scholarly literature (Bakker et al., 2005; Wood et al., 2014; Mase et al., 2017). This method was suggested for use in this paper by agricultural economist David Conner, Ph.D. The approach was confirmed to be appropriate through a review of literature, and then verified and guided in practice for this study by statistician Alan Howard at the University of Vermont.

In this study, specific binomial logistic regression models (generalized linear models assuming binomial distribution with the logit link function) were fit to predict the probability of adopting each adaptive management practice. Adaptation strategies are used as dependent variables in the model, and explanatory variables are the site and soil characteristics listed in table 1. The logit model predicts the likelihood of using an adaptive management practice based on having site and soil characteristics. Within the dataset, missing values were replaced with n/a. Binary variables (0,1) were converted to factors prior to running models. Analysis was conducted using R Studio software. Code for running the model used the glm function, with family = binomial and a logit link. As an example, code for predicting the use of permanent mulch to adapt to heavy precipitation would look like the following:

```
> Adaptlogitna$precip_mgmt_perm_mulch  <- as.factor(Adaptlogitna$precip_mgmt_perm_mulch)

>model <-
glm(precip_mgmt_perm_mulch~soil_clay+soil_sand+soil_silt+soil_loam+soil_gravel+soil_ledge+site_
vulnerabilities_floodplain+site_vulnerabilities_steep_slopes+site_vulnerabilities_wind_exposure,fam
ily=binomial(link='logit'),data=Adaptlogitna)

> summary(model)
```

3.3.4 Dependent variables: Adaptation strategies

We reference our research from Chapter 2 to identify trends in how vegetable and berry farmers in the Northeastern US are adapting to precipitation extremes. These practices and strategies emerged from qualitative and quantitative data analyses. Quantitative data was collected on most of these strategies, and can be used to statistically link the site and soil characteristics reported by survey participants to adaptive management practices.

Adapting to excess water. Vegetable and berry growers in the northeast identified the use of raised beds, drainage strategies, cover cropping, soil health, crop rotations, and green manures, hoop houses, reduced tillage, no-till, storm water management, perennial plantings, and mulch as the primary strategies and practices which help them to manage for the risk of increased precipitation and flooding.

Adapting to water deficits. Vegetable and berry growers in the northeast identified the use of irrigation, organic fertilizers, cover crops, mulch, efficient irrigation, water harvesting, and general soil building as the primary strategies and practices which help them to manage for the risk of increased precipitation and flooding.

3.3.5 Explanatory variables: Site characteristics

Soil texture. Soils are the primary interface for regulating water availability to crops, and the type of soil affects the fate of precipitation, at either extreme, with important implications for farm management. In *sandy* soils, a high proportion of incoming water will infiltrate and drain quickly (in the absence of a subsurface restrictive layer), whereas *clay* soils resist infiltration, but hold moisture longer (Brady & Weil, 2008). *Silt* is the particle size which falls between sand and clay in size. *Loam* is a highly regarded texture class, which refers to a soil with a mix of the three particle sizes (sand, silt, clay) and exhibits the best properties of the extremes (i.e. drains well, holds moisture, and retains nutrients). Loams are common, highly regarded by farmers as a prime soil for agriculture, and occur naturally in floodplains. In our study, we asked farmers to identify the occurrence of these major soil textures for use as explanatory variables.

Rock fragments & geologic features. The presence of rock fragments in soils can significantly alter the impacts of climatic changes (Poesen & Lavee, 1994) by influencing infiltration, water holding capacity, ponding and erosion, and cause an overall reduction in losses of soil and water (Poesen & Lavee, 1994; Cerda, 2001). Depth to bedrock exerts a first order control of the ability of a soil to store and transmit water (Zhu & Lin, 2011). Thus, we asked farmers to identify the presence of *gravel* and *ledge* in their farmland and include them as explanatory variables.

Landscape features which intensify weather impacts. We identified three additional site characteristics as potential drivers of adaptive management decisions because they intensify the risks associated with precipitation extremes. Highly erodible land (HEL) is classified by the NRCS as being exposed to forces of wind erosion, and, "long and steep slopes, with soils susceptible to erosion and increased vulnerability to high rates of runoff during heavy rains" (Morton et al., 2015). Increases in intensity and frequency of heavy precipitation events may cause an intensification in flooding events and erosion on steep slopes. Drought conditions are also associated with increased erosion when combined with wind exposure (Valentin, 1996). Thus, we included *wind exposure, steep slopes* and *floodplains* as explanatory variables in our study.

Table 6. Frequency of site and soil characteristics reported by survey respondents

Site and soil characteristics identified in the survey, and number of respondents									
	Soil characteristics						Site characteristics		
	Sandy soil	Silty soil	Clay soil	Loam soil	Gravel	Ledge	Floodplain	Steep slopes	Windy
n	70	56	65	134	19	26	41	76	97

3.3.6 Regression modeling and interpretation

Binomial logistic regression models preformed for this study yielded a summary of the model statistics, an example of which is shared in Table 7. The logistic regression coefficients represent the change in the log odds of the outcome for each one unit increase in the predictor variable (UCLA, 2018). The logistic regression model is:

$$\text{logit}(p) = \log(p/(1-p)) = \beta_0 + \beta_1 * \mathbf{x1} + \ldots + \beta_k * \mathbf{xk}$$

As an example, in Table 7, we see that having clay soils increases the log odds ratio of using raised beds by 0.9381. The odds are the ratio of the probability of using to the probability of not using a practice, and the relationship should be interpreted as correlational. The sign indicates if the relationship between variables is negative or positive. The P-values should be interpreted as a test that the coefficient (log odds ratio) is significantly different from zero, or that the odds ratio (p/1-p) is significantly different from 1. We use an alpha threshold of 0.05 as significant, and following Burnham and Anderson (2002) also report a mild significance threshold as less than 0.10.

Table 7. Logit model for using raised beds to manage for risk of heavy precipitation based on site characteristics

Dependent variable: Use of **raised beds** to manage for risk of heavy precipitation and flooding				
Explanatory variables	Coefficient	Standard Error	Z value	P
Clay	**0.9381**	**0.4073**	**2.303**	**0.0213 ***
Sandy	-0.1688	0.3733	-0.452	0.6512
Silty	-0.2436	0.3810	-0.639	0.5226
Loam	0.1364	0.4166	0.327	0.7434
Gravel	1.0270	0.6226	1.650	0.0990 .
Ledge	-0.5216	0.4866	-1.072	0.2838
Floodplain	0.3226	0.4617	0.699	0.4847
Steep slopes	**1.0299**	**0.4185**	**2.461**	**0.0139 ***
Wind exposure	0.1013	0.4146	0.244	0.8070
Null deviance: 198.93 Degrees of freedom: 143 n= 144 Significance codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1				

The odds ratio is a more useful number for interpretation of the results, so we transformed the coefficients from the modeling. To get the odds ratio, we calculate the coefficient used as the exponent base e, using the following equation:

e^[coefficient] = p/p-1

We summarize the results of our modeling in two tables. In table 3 we report the coefficients, and in table 4 we report the odds ratios. The odds ratio is interpreted as a measure of how many times more likely will someone use that management practice if they have that site or soil characteristic, compared to those who don't have that soil/site characteristic.

3.4 Results

The results of our study indicate that farmers consider their unique site and soil characteristics when making adaptive decisions. Some practices evaluated in our study are strongly tied to site and soil characteristics, whereas other practices, like green manures, are utilized to adapt to increasing precipitation extremes regardless of site characteristics. Practices which were highly correlated with soil and site characteristics include the use conservation irrigation on sandy soils, the use of perennial plantings and permanent mulch on steep slopes, and the use raised beds on clay soils and steep slopes. Interestingly, crop diversification was correlated with use on floodplain sites in our sample. Overall, our study shows that site and soil conditions are important considerations for adaptive decision-making and are determinants of site-appropriate adaptive management strategies on farms.

3.4.1 Farmer perspectives on how site characteristics drive adaptive management

Grower's think about adaptive management with their specific site characteristics in mind and consider land form, soil type and flood risk as important determinants in decision-making. Farmers know that soil type impacts water availability, as in "we farm on heavy clay and it stays pretty moist generally" or "I live on sandy hilltop." One producer who participated in the study explained about making adjustments to plant locations based on drainage characteristics of the soil; “we have changed to mostly perennial fruits but have had to modify where we plant things based on sandy dry areas and heavy wet areas.” Another grower explained how the water retention in sandy soil could be improved through organic matter additions; “we have excessively drained sandy loam, so we need to build organic matter for H20 retention.” Whereas a grower with poorly drained soil described using off-contour beds to increase drainage; “have clay soils-- use gently sloping hillside on perpendicular.” Farmers also shared strategies to limit erosion on slopes, such as “planning more perennials on slopes,” and “increasing land forming on slopes to reduce potential erosion” in the form of berms, terraces, and raised beds.

Farmers with multiple fields are able to plan or rotate to better manage the risks associated with extreme precipitation patterns, and make cropping decisions vary based on the different hydrologic features of their fields. One growers reported that, “we've started growing ‘gamble’ crops in our most flood-prone fields and have moved our most important crops to higher/safer fields.” Another said, “our heavy ground is very fertile but hard to access early in the season. We have other leased fields that are of a gentle slope with lots of ledge. Very well drained and workable early in spring,” explaining how drainage characteristics of soils influence management timing and rotation decisions.

Additionally, site characteristics are often a reason that growers have not adapted. For example, growers with heavy clay soils are unlikely to experience water deficit stress. One grower said, “Never experienced drought in 40 years. I have a clay loam soil, I welcome it!” Whereas farmers with sandy soils will have less issues with water-logging, as in “soil is sandy so except for a lower part of my property not too much of a problem.”

Overall, site and soil characteristics are important determinants of general farming decisions, and it is not surprising that adaptive management decisions are also influenced by site and soil characteristics.

3.4.2 Model results and odds ratios

The results of our logistic regression modeling highlight relationships between site and soil characteristics, that reinforce major themes from the direct quotes. In table 8 we report the coefficients for all models, and in table 9 we report the odds ratios for all models. The odds ratio is interpreted as a measure of how many times more likely will someone use that management practice if they have that site or soil characteristic, compared to those who don't have that soil/site characteristic.

Soil building as a strategy is used broadly across soil and site characteristics to adapt to increased incidence of drought. However, some soil building strategies are correlated with risk management of heavy precipitation on sites that have steep slopes or rock features (table 9). Specifically, sites with gravel are 8.5 times more likely to use organic fertilizers to manage for the risk of heavy precipitation than sites without ($p>.05$). Sites with steep slopes are 3 times more likely to use cover cropping, and 2.5 time more likely to use reduced tillage ($p>.05$). Sites with ledge are 2.3 times more likely to use reduced tillage or no-till to manage for the risk of heavy precipitation (to a mild significance level of $p>.1$).

Adaptive crop planning strategies and practices offer some interesting insights into planting trends. On steep slopes, the odds of using perennial plantings to adapt to heavy precipitation is 5.8 times more likely than on sites without steep slopes ($p>.001$), and 3 times more likely for drought management (p>.05). On farms in the floodplain crop diversification is 2.3 to 2.5 times more likely to be used to manage for both drought and heavy precipitation (to a mild significance level of p>.1). Floodplain farms are also correlated with the 3.6 times the use of crop rotations (p>.05) and 2.3 times the use staggered harvest dates to address heavy precipitation (table 9). Sandy soils are correlated with later planting dates for managing heavy precipitation risk, and the use of crop diversification, shorter season varieties and perennials to address drought. By comparison, loam soils are negatively correlated with both the use of shorter season varieties and crop rotations for addressing drought.

Farmers have a number of practices which they can use to control water on their land. Some strategies for controlling water are intended to protect crops and soils from forces of erosion, flooding and water-logged soils. Other strategies help to increase water availability to crops during times of drought and water deficits. Increased irrigation is one of the most popular adaptive strategies for drought reported among these respondents (White et al., 2018) and it is not significantly tied to site characteristics in this dataset. The use of efficient irrigation, also called conservation irrigation, is negatively associated with use on sites that reported ledge, or shallow depth to bedrock, features, but it is 4 times more likely to be used on sandy soils (p>.01), and 2.7 times more likely to be use on sites with silty soils (p>.05). The use of raised beds to address heavy precipitation risk is 2.8 times more likely on sites with steep slopes (p>.05) and 2.5 times more likely on sites with clay soils (p>.05). Using keyline is mildly correlated with have clay soils and sandy soils. And finally, the use of permanent mulch is 5 times more likely on steep slopes(p>.001), and 4 times more likely in the floodplain(p>.05).

Clay is not correlated with any drought management strategy or practice, which reinforces the quote from the grower who said “Never experienced drought in 40 years. I have a clay loam soil, I welcome it!” Farmers who have clay soils do not experience strong drought impacts, and have not needed to adapt their management for it. Notably, windy sites are not robustly correlated with any strategy, only weakly correlated with the use of crop diversification.

Table 8. Results for all logit models, with coefficients and signs indicating positive and negative correlation

Coefficients for Managing Heavy Precipitation

	Explanatory variables								
	Soil characteristics						Site characteristics		
Dependent variables	Clay	Sandy	Silty	Loam	Gravel	Ledge	Floodplain	Steep slopes	Wind exposure
Soil Building									
Soil health	-0.655	-0.390	-0.298	0.535	-0.330	0.577	0.742	0.198	-0.187
Organic fertilizers	0.494	0.129	-0.629	0.288	**2.138 ***	-0.084	0.521	0.619	-0.496
Cover cropping	-0.651	-0.557	0.465	0.325	0.323	-0.316	0.681	**1.126 ***	0.598
Green manures	-0.101	0.072	0.152	0.507	-0.457	-0.333	-0.334	0.220	-0.171
Reduced Tillage	-0.329	0.583	-0.400	0.046	0.107	**0.844 .**	0.170	**0.952 ***	0.059
No Till	0.234	0.125	0.113	0.516	0.704	**0.832 .**	0.569	0.498	0.250
Crop Planning									
Crop diversification	-0.038	-0.036	0.108	0.295	**-0.967 .**	-0.576	**0.921 .**	0.142	0.315
Crop rotations	0.106	-0.095	0.262	0.343	-0.322	0.104	**1.284 ***	-0.589	0.558
Later planting dates	0.462	**0.875***	0.020	0.223	0.383	-0.350	0.527	-0.163	0.145
Staggered harvest dates	-0.146	0.321	-0.162	0.334	-0.739	0.109	**0.832 .**	0.082	0.229
Perennial plantings	0.269	0.502	0.396	0.412	0.077	0.252	-0.222	**1.759 *****	0.281
Water Control									
Raised Beds	**0.938***	-0.169	-0.244	0.137	**1.027 .**	-0.522	0.323	**1.03***	0.101
Drainage, tile	0.421	0.763	-0.246	-0.085	0.107	-0.399	-0.353	-0.081	-0.403
Drainage, not tile	0.678	-0.189	0.618	-0.455	0.555	0.619	-0.531	-0.176	-0.123
Storm water management	0.121	-0.748	0.052	-0.210	-1.038	0.562	0.327	0.093	-0.162
Keyline	**1.067 .**	**1.073 .**	-0.283	0.856	-0.042	-0.488	0.758	-0.047	0.017
Hoop house	-0.137	-0.007	**- 0.73 .**	-0.278	-0.957	0.210	0.704	0.439	0.014
Permanent mulch	0.219	0.319	-0.049	-0.308	0.300	0.448	**1.379 ***	**1.627 ****	0.058

Each row represents an individual logistic regression. The numbers reported represent partial regression coefficients, representing the log odds ratio of the site characteristic in predicting the dependent variable, adaptive management practice. Bolded and highlighted numbers are significant. Significance codes are reported as: ‘ ***’ $p < 0.001$ ‘ **’ $p < 0.01$ ‘ *’ $p < 0.05$ ‘ .’ p < 0.1

Table 8. continued… Results for all logit models, with coefficients and signs indicating positive and negative correlation

Coefficients for Drought Management

	Explanatory variables								
	Soil characteristics						Site characteristics		
Dependent variables	Clay	Sandy	Silty	Loam	Gravel	Ledge	Floodplain	Steep slopes	Wind exposure
Soil Building									
Soil health	0.279	0.282	0.263	**0.77 .**	-0.461	-0.125	-0.097	-0.331	-0.093
Organic fertilizers	-0.380	0.358	0.103	-0.564	-0.568	-0.158	0.199	-0.218	0.181
Cover cropping	0.091	0.018	0.446	0.067	0.094	-0.707	0.037	0.140	0.421
Green manures	-0.202	0.141	0.150	-0.105	-0.434	-0.351	-0.026	-0.083	-0.238
Crop Planning									
Crop diversification	0.030	**0.754 ***	0.363	-0.282	-0.393	0.515	**0.814.**	0.296	**0.72 .**
Crop rotations	-0.047	0.436	0.471	**-0.725 .**	-0.217	-0.253	0.773	0.224	0.806
Shorter season varieties	0.350	**1.274 ***	0.017	**-1.723 ****	**1.326 .**	-0.889	0.848	-0.234	0.194
Perennial plantings	0.525	**0.712 .**	0.098	0.189	0.105	0.586	0.187	**1.097 ***	0.719
Drought tolerant varieties	0.277	0.176	0.603	0.101	**-1.44 .**	-0.068	0.096	-0.489	0.145
Water Control									
Increased irrigation	-0.484	-0.117	0.103	-0.542	0.486	0.435	0.124	-0.238	-0.386
Efficient irrigation	0.253	**1.368 ****	**0.978 ***	-0.369	-0.338	**-1 .**	-0.486	-0.126	0.192
Permanent mulch	-0.547	0.268	-0.299	0.193	0.677	-0.282	1.106	0.203	0.513

Each row represents an individual logistic regression. The numbers reported represent partial regression coefficients, representing the log odds ratio of the site characteristic in predicting the dependent variable, adaptive management practice. Bolded and highlighted numbers are significant. Significance codes are reported as: '***' $p < 0.001$ '**' $p < 0.01$ '*' $p < 0.05$ '.' p <

Table 9. Odds ratios for all logit models

Odds Ratios for Managing Heavy Precipitation

	Explanatory variables:								
	Soil characteristics						Site characteristics		
Dependent variables	Clay	Sandy	Silty	Loam	Gravel	Ledge	Floodplain	Steep slopes	Wind exposure
Soil Building									
Soil health	0.519	0.677	0.742	1.707	0.719	1.781	2.100	1.219	0.830
Organic fertilizers	1.639	1.138	0.533	1.334	**8.482 ***	0.920	1.684	1.858	0.609
Cover cropping	0.522	0.573	1.592	1.384	1.381	0.729	1.976	**3.083 ***	1.819
Green manures	0.904	1.075	1.165	1.660	0.633	0.717	0.716	1.247	0.842
Reduced Tillage	0.720	1.791	0.670	1.047	1.113	**2.326 .**	1.185	**2.591 ***	1.061
No Till	1.264	1.133	1.120	1.675	2.021	**2.298 .**	1.766	1.645	1.284
Crop Planning									
Crop diversification	0.963	0.965	1.114	1.344	**0.380 .**	0.562	**2.512 .**	1.153	1.370
Crop rotations	1.112	0.910	1.300	1.409	0.725	1.110	**3.611 ***	0.555	1.747
Later planting dates	1.587	**2.399 ***	1.020	1.250	1.467	0.705	1.694	0.850	1.156
Staggered harvest dates	0.864	1.378	0.850	1.396	0.478	1.115	**2.298 .**	1.086	1.258
Perennial plantings	1.308	1.652	1.486	1.510	1.080	1.286	0.801	**5.807 *****	1.324
Water Control									
Raised Beds	**2.555 ***	0.845	0.783	1.147	**2.793 .**	0.593	1.381	**2.801 ***	1.106
Drainage, tile	1.523	2.145	0.782	0.919	1.113	0.671	0.702	0.922	0.668
Drainage, not tile	1.970	0.828	1.856	0.634	1.742	1.858	0.588	0.838	0.884
Storm water management	1.129	0.474	1.053	0.811	0.354	1.755	1.387	1.098	0.850
Keyline	**2.907 .**	**2.9241 .**	0.754	2.354	0.959	0.614	2.134	0.954	1.017
Hoop house	0.872	0.993	**0.482 .**	0.757	0.384	1.234	2.022	1.551	1.014
Permanent mulch	1.245	1.376	0.952	0.735	1.349	1.565	**3.971 ***	**5.089 ****	1.059

Each row represents an individual logistic regression. The numbers reported represent odds ratios, indicating the weight of the site characteristic in predicting the use of an adaptive management practice. Bolded and highlighted numbers are significant. Significance codes are reported as: '***' $p < 0.001$ '**' $p < 0.01$ '*' $p < 0.05$ '.' $p < 0.1$

Table 9. continued… Odds ratios for all logit models

Odds Ratios for Drought Management

	Explanatory variables:								
	Soil characteristics						Site characteristics		
Dependent variables	Clay	Sandy	Silty	Loam	Gravel	Ledge	Floodplain	Steep slopes	Wind exposure
Soil Building									
Soil health	1.321	1.325	1.300	**2.16 .**	0.630	0.883	0.908	0.718	0.911
Organic fertilizers	0.684	1.430	1.108	0.569	0.567	0.854	1.220	0.804	1.198
Cover cropping	1.096	1.018	1.562	1.069	1.099	0.493	1.038	1.150	1.524
Green manures	0.817	1.151	1.162	0.900	0.648	0.704	0.974	0.921	0.788
Crop Planning									
Crop diversification	1.030	**2.125 ***	1.438	0.754	0.675	1.674	**2.257 .**	1.345	**2.054 .**
Crop rotations	0.954	1.547	1.601	**0.484 .**	0.805	0.776	2.167	1.252	2.239
Shorter season varieties	1.420	**3.575 ***	1.017	**0.1789 ******	**3.766 .**	0.411	2.335	0.791	1.215
Perennial plantings	1.691	**2.038 .**	1.103	1.208	1.111	1.797	1.206	**2.996 ***	2.051
Drought tolerant varieties	1.320	1.193	1.828	1.106	**0.237 .**	0.934	1.101	0.613	1.156
Water Control									
Increased irrigation	0.616	0.890	1.108	0.582	1.625	1.545	1.132	0.788	0.680
Efficient irrigation	1.287	**3.927 ******	**2.659 ***	0.692	0.713	**0.368 .**	0.615	0.881	1.211
Permanent mulch	0.579	1.307	0.741	1.213	1.968	0.754	3.023	1.225	1.670

Each row represents an individual logistic regression. The numbers reported represent odds ratios, indicating the weight of the site characteristic in predicting the use of an adaptive management practice. Bolded and highlighted numbers are significant. Significance codes are reported as: ‘ ***’ $p < 0.001$ ‘ **’ $p < 0.01$ ‘ *’ $p < 0.05$ ‘ .’ $p < 0.1$

3.4 Discussion

3.4.1 Theoretical implications

Local farmer's knowledge has an important role to play in informing research on agricultural adaptation to climate change. Farmers are adapting their management to account for changes in the climate and making adaptive decisions based on understandings of the site-specific vulnerabilities of their farm. Our analysis supports the assertion that adaptive management strategies are often site-specific. This aligns with conceptual frameworks where agroecosystem characteristics & livelihood assets define system vulnerability, and thus the appropriate adaptive interventions, strategies & techniques (Janowiak et al., 2016). Interestingly, some strategies are adaptive across any site, but some practices are uniquely suited to manage climate related risks on certain sites. Our study supported the theory that soil building is broadly applicable principle for agricultural resilience, but suggests that crop diversification may be more nuanced in its interaction with site characteristics and may not be a principle of resilience for all sites. This complicates the theoretical foundations of agroecological principles and strategies that should be applicable to all site and contexts, and emphasizes the importance of evaluating the environmental complex of an agroecosystem (Gliessman, 2006).

Additionally, our study confirms that among vegetable and berry growers of the Northeast, farmer's local knowledge of site vulnerabilities and water management align with assertions from fields of soil science, conservation agriculture and agroecology. This reinforces the value of including farmers as partners and collaborators in research and resource development.

3.4.2 Practical implications

Our findings imply that climate risk management planning on farms should start with a thorough assessment of the site-specific characteristics and vulnerabilities of each site. Soil type influences both the level of concern and the necessary adaptation measures for drought considered by growers. While clay soils are far less vulnerable to water deficits, sandy and well-drained soils require significantly more supplemental water during times of drought, perhaps more than can be achieved by soil building and increases in organic matter alone. Raised beds systems are as appropriate for managing waterlogging in heavy soils, as they have been in traditional agriculture for centuries, and can be used on contour like terraces to control erosion and water flows. Soil building strategies are broadly applicable and should be encouraged across all site characteristics.

Resources geared towards agricultural climate resilience should take into account site characteristics, and integrate local farmers perspectives and experiences in determining local site appropriate developments. Local farmer's knowledge is an ideal starting place for developing adaptation resources that reflect the unique site conditions of a farming community. Resources can be organized by site characteristic and soil type to meet farmers' needs for localized and context specific information.

3.4.3 Limitations

Our sample size is adequate to perform this regression modeling approach; however, a larger sample size might give us stronger results. A low number of respondents reported ledge and gravel on their sites, and a larger sample with those site characteristics could influence those coefficients. There is also the potential of collinearity between variables, which would complicate the results. Our sample was limited to vegetable and berry growers in the northeastern US, and thus the results are not directly applicable to other production sectors or regions.

3.4.4 Future research

Further research is needed to assess if and how crop diversification is correlated with site and soil characteristics. Our study focused on how site and soil characteristics influence adaptive management, yet we know that adaptation is influenced by many different factors beyond the biophysical characteristics and features of the farm. Future research should consider how site and soil characteristics interact with other drivers of adaptation and adaptive capacity to offer a more holistic perspective on adaptive decision making. Our approach should be tested in other production sectors, and in other regions, to compare how regional and production context factors change the influence of site and soil characteristics on adaptation.

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CHAPTER 4: INTEGRATIVE DISCUSSION AND CONCLUSION

My interest in this work was forged from a desire to serve my agricultural community, combined with a passion for applied research grounded in deep listening. The need for tailored and context specific information which I heard expressed by both extension and farmers drove the design of my research project, but I found myself as excited and interested in the process and approach as I was in the resulting information. The dynamic knowledge system of sustainable agriculture networks in the region combined with the principles of participatory action research and the often politically charged nature of climate change made for an exciting context in which to pursue my masters research. I found myself drawing upon the skills I learned from working in grassroots organizing and for small businesses in order to communicate and engage with different stakeholders over the last year and a half.

From a participant observer perspective, this work is needed and recognized as urgently important by farmers across the northeastern US. The value of asking farmers for their perspectives and involving them in the research process cannot be understated. Farmers adapt to stresses and changes in their environment with or without scientists as partners, and often work together to solve new problems. Where agroecology has emphasized the value of local knowledge and inspired the Farmers First approach I drew on for this work, my own experience in this research process has doubled my interest in supporting the capacity of extension and advisors to meet farmers needs through reflexive and well-funded relationships, as they are often the primary people farmers look to for vetting ideas and providing support.

In the space I conducted my research, land management decisions are likely influenced by many larger contextual things than were documented in the survey, such as educational programs, policies, extension agents, markets, and culture. I understand the limitations of my research as documenting the expression of local farmers against all of the contextual influences in this site. However, unpacking this complexity is well met by the inductive farmer-focused approach we used, and follow-up research can better account for the most salient forces and opportunities in this space. As well, the politically engaged, transformative agroecology informed by participatory action approach presented by Mendez et al., (2016) and Gonzalez de Molina (2016) brings to the fore a consideration of the complex challenges and power dynamics facing and influencing land managers in their transition toward sustainability and resilience. This is a dimension of climate change adaptation which I have regrettably not broached in my masters thesis, but deserves ample consideration by researchers, and I hope to address in the next phase of my academic career.

Though I emphasize the way this research meets locality and context specific information needs, there are likely many ideas that can be applied to other places and production contexts to support research ideas and inform farmer adaptations. The survey report has already attracted attention from Extension, NRCS and land grant university researchers across the region and into the Midwest, and will hopefully have a positive impact on ideas brewing out there to better serve farmers in adapting to climate change.

The original survey report (White et al., 2018) was written to present the most simple version of the results, with little interpretation. My goal was to retain as much of the original character of the raw data as possible in the document and allow farmers and other readers to draw their own conclusions and inspiration from it, so I tried to report themes in the voices and lexicon of farmers, while also organizing the information to make it easier to read and reference. Reflecting back on the PAR and co-production theory which guided my process, the survey report represents a boundary object, bridging the space between research practice. It fulfills the definition of boundary object, foremost as having interpretive flexibility (Leigh Star, 2010), and generating different meaning and use for different audiences who read it. It is a thing, that exists in a shared space between science and farming, but the last piece of the definition—the dynamic between the way it is used versus its tailored use is being discovered now.

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APPENDIX A: SURVEY INSTRUMENT

New England Adaptation Survey

Welcome!

This survey has a few sections. It should take you about 15 minutes. We are interested in learning about:

1) your experience with extreme and variable weather,

2) how you are adapting to heavy precipitation,

3) how you are adapting to increasing incidence of drought,

4) your information sources and,

5) benefits of cover crops, and

6) some basic information about you and your farm.

Thank you for taking this survey! To complete the survey and share your answers with the researchers, please be sure to click the validate button on the last page.

What is your zip code? ________________

Are you a farmer?

☐ Yes, I own a farm

☐ Yes, I work full time on a farm

☐ I work part time on a farm

☐ I don't work on a farm, but I do work with farmers

☐ Other ________________

This survey is designed to collect information specific to vegetable and fruit production.
Please tell us what you grow on your farm:

☐ Vegetables

☐ Berries

☐ Tree Fruits

☐ Other ______________________________

Questions about how you are Adapting to Heavy Precipitation.
This set of questions is about how you deal with heavy precipitation and flooding. Another set of questions will ask you about your experience with drought.

Please select the practices you use to manage heavy precipitation and flooding on your farm. (You may use these practices for other reasons, but this question is asking JUST about managing heavy precipitation and flooding.)

- ☐ Hoop houses/high tunnels
- ☐ Reduced Tillage (such as zone or strip tillage)
- ☐ Key-line plowing or deep tillage
- ☐ No Till
- ☐ Building soil health/ soil quality
- ☐ Adding composts & manures
- ☐ Cover crops
- ☐ Green manure (crop residue incorporation into soil)
- ☐ Crop rotation
- ☐ Planning staggered harvest dates
- ☐ Later planting dates
- ☐ Earlier planting dates
- ☐ Longer season crops & cultivars
- ☐ Shorter season crops & cultivars
- ☐ Crop diversity
- ☐ Perennial plantings
- ☐ Planting moisture tolerant crops & cultivars
- ☐ Permanent mulch
- ☐ Irrigation (automated, drip, overhead)
- ☐ Storm water catchment (detention pond or rain garden)
- ☐ Conservation buffer strips (riparian buffers, wind breaks, stream corridors, buffer strips, shelter belts, hedgerows)
- ☐ Raised beds
- ☐ Drainage tile
- ☐ Drainage, not tile (e.g ditching, berms)
- ☐ Insurance (farm policies, crop insurance, product liability)
- ☐ Financial Analysis/Planning
- ☐ Market diversification
- ☐ Enterprise Diversity
- ☐ Off-farm Income
- ☐ OTHER ______________________________

Questions about how you are Adapting to Heavy Precipitation.

This set of questions is about how you deal with heavy precipitation and flooding. Another set of questions will ask you about your experience with drought.

Have you made any *changes* on your farm because of an experience with, or concern about, heavy precipitation or flooding?

- ◯ Yes
- ◯ No

What changes have you made on your farm because of this experience with heavy precipitation or flooding?

____

Are you *planning* to make any changes that will help you manage for the risk of heavy precipitation or flooding?

- ◯ yes
- ◯ no

What changes are you planning to make in the near future which will help you manage for the risk of heavy precipitation or flooding?

____

In your opinion, what is the most promising, interesting or innovative strategy for adapting to heavy precipitation and flooding that you have heard about?

____

What advantages do you think this strategy offers?

____

What do you think the drawbacks and challenges of this strategy are, or would be, for you?

____

Questions about how you are Adapting to Drought

Please select the practices you use to manage drought on your farm. (You may use these practices for other reasons, but this question is asking JUST about managing drought.)

- [ ] Conservation buffer strips (riparian buffers, wind breaks, stream corridors, buffer strips, shelter belts, hedgerows)
- [ ] Cover Crops
- [ ] Green manure (crop residue incorporation into soils)
- [ ] Reduced Tillage (zone, strip)
- [ ] No till
- [ ] Building Soil Health/ Soil Quality
- [ ] Organic Fertilizers (composts)
- [ ] Efficient Irrigation (Using water more efficiently)
- [ ] Increased Irrigation
- [ ] Drainage, not tile
- [ ] Crop diversity
- [ ] Crop Rotation
- [ ] Shorter season crops & cultivars
- [ ] longer season crops & cultivars
- [ ] Planting drought tolerant crops & cultivars
- [ ] Variety in maturity period
- [ ] Permanent Mulch
- [ ] Heat tolerant crops
- [ ] Later planting dates
- [ ] Earlier planting dates
- [ ] Perennial plantings
- [ ] Insurance (farm policies, crop insurance, product liability)
- [ ] Financial Analysis/Planning
- [ ] Market diversification
- [ ] Enterprise diversity
- [ ] Off Farm Income
- [ ] OTHER ______________________________

Questions about how you are Adapting to Drought

Have you made any changes on your farm because of an experience with, or concern about, drought?

- ◯ Yes
- ◯ No

What changes have you made on your farm because of this experience with drought?

Are you planning to make any changes because of your experience with drought?

- ◯ Yes
- ◯ No

What changes are you planning to make in the near future which will help you manage for the risk of drought?

In your opinion, what is the most promising, interesting or innovative strategy for adapting to drought?

What advantages do you think this strategy offers?

What do you think the drawbacks and challenges of this strategy are, or would be, for you?

Questions about Networks & Information

What farming groups and networks are you a member of, or get information from?

- ☐ SARE
- ☐ CISA
- ☐ MOFGA
- ☐ NE VBGA
- ☐ NOFA NH
- ☐ NOFA MA
- ☐ NOFA VT
- ☐ Permaculture groups
- ☐ VT VBGA
- ☐ ME FBGA
- ☐ Farm Bureau
- ☐ New England Farmer's Union
- ☐ Greenhorns
- ☐ None
- ☐ OTHER ______________________

Questions about Networks & Information

In your experience, what are the best sources of information on innovative and adaptive approaches to new challenges you encounter on your farm?

- ☐ Other farmers
- ☐ University Extension
- ☐ Other agricultural advisors
- ☐ NRCS
- ☐ Farmer organizations
- ☐ Seed companies
- ☐ Magazines
- ☐ Social Media
- ☐ Internet Videos
- ☐ List-servs
- ☐ State department of agriculture
- ☐ USDA Climate Hubs
- ☐ Books
- ☐ Agricultural supply businesses
- ☐ Family & Friends
- ☐ Personal experience & innovation
- ☐ Peer Reviewed Journals
- ☐ Websites
- ☐ Conferences
- ☐ Scientists
- ☐ OTHER ____________________

Questions about Cover Crops

Do you use cover crops?

- ◯ Yes
- ◯ No

What benefits to you think you get from using cover crops? Please indicate your level of agreement with the following statements:

Agree or Disagree: *Where 1 represents strongly disagree, and 5 represents strongly agree*	1 disagree	2	3	4	5 agree
Using cover crops on my farm has increased my resilience to drought.	◯	◯	◯	◯	◯
Using cover crops on my farm has helped protect my soil from erosion.	◯	◯	◯	◯	◯
Using cover crops on my farm has buffered the impacts of flooding.	◯	◯	◯	◯	◯
Using cover crops on my farm has reduced the negative impacts of intense heat.	◯	◯	◯	◯	◯
Using cover crops on my farm has increased my yields.	◯	◯	◯	◯	◯
Cover crops capture and hold nitrogen in my soils.	◯	◯	◯	◯	◯
Cover crops have improved the overall health of my soils.	◯	◯	◯	◯	◯
Cover crops have helped my yields be more consistent despite variable and extreme weather.	◯	◯	◯	◯	◯
Cover crops protect my soil from wind damage.	◯	◯	◯	◯	◯
Cover crops improve the drainage of my soil.	◯	◯	◯	◯	◯
Cover crops improve the water holding capacity of my soil.	◯	◯	◯	◯	◯
Using cover crops reduces my need for other fertilizer inputs.	◯	◯	◯	◯	◯
I use cover crops because they can sequester atmospheric carbon and reduce global warming.	◯	◯	◯	◯	◯
Cover crops increase habitat for pollinators and other beneficial insects on my farm.	◯	◯	◯	◯	◯

Questions about Cover Crops

What are the drawbacks of using cover crops? Please indicate your level of agreement with the following statements:

Agree or disagree: *Where 1 represents strongly disagree, and 5 represents strongly agree*	1 disagree	2	3	4	5 agree
Using cover crops makes my farm planning more complex.	○	○	○	○	○
Cover crop seed is too expensive	○	○	○	○	○
I do not have enough time to sow and manage cover crops optimally	○	○	○	○	○
I do not have enough land to sow and manage cover crops optimally	○	○	○	○	○
I do not have enough equipment to sow and manage cover crops optimally	○	○	○	○	○
When my farm business suffers financially I am less likely to use cover crops	○	○	○	○	○

I would use more cover crops if...

____

Please describe your farm and experience

How many total acres do you farm?
(Total acres in production or rotation this year.)

____

How many acres are certified organic?

____

Dominant soil types on my farm include:

- ☐ Sand
- ☐ Silt
- ☐ Clay
- ☐ Loam
- ☐ Gravel
- ☐ Ledge
- ☐ OTHER ____

Please describe your farm and experience

My farmland includes these vulnerabilities:

- [ ] Floodplain
- [ ] Steep Slopes (prone to erosion)
- [ ] Areas exposed to high winds

How many years have you been a primary decision maker on a farm? ____________

What is your highest level of education?

- ◯ Some formal education, Less than high-school
- ◯ High school graduate/GED
- ◯ Some college
- ◯ 2-year college/technical degree
- ◯ 4-year college degree
- ◯ Graduate degree (MS, MD, PhD, etc.)

Gross Annual Farm Income

- [ ] less than $1,000
- [ ] $1,001 - $49,000
- [ ] $50,000 - $149,000
- [ ] $150,000 - $349,000
- [ ] $350,000 - $999,999
- [ ] $1,000,00 - $4,999,999
- [ ] more than $5,000,000

Estimated % of your total household income supported by your farm business: (Select one)

- ◯ 0-5%
- ◯ 10%
- ◯ 20%
- ◯ 30%
- ◯ 40%
- ◯ 50%
- ◯ 60%
- ◯ 70%
- ◯ 80%
- ◯ 90%
- ◯ 100%

How old are you? ____________

What is your gender?

- [ ] Male
- [ ] Female
- [ ] Non-gender conforming
- [ ] Prefer not to answer

Experience and Concern about Extreme Weather

The following is a list of some weather challenges that farms in the northeast have experienced. When you think about the impact they have had on your own farm, how concerned are you about these challenges?

Level of concern *1 represents no concern, and 4 represents highly concerned*	1	2	3	4
Increases in saturated soils and ponded water	○	○	○	○
Increases in river flooding events	○	○	○	○
Increases in flash flooding events	○	○	○	○
Increases in erosion	○	○	○	○
Loss of nutrients due to heavy and abundant precipitation	○	○	○	○
Increased incidence of crop disease & fungal diseases (related to moisture)	○	○	○	○
Longer dry periods or drought	○	○	○	○
Increasing heat stress on my crops	○	○	○	○
Reduced winter snow cover	○	○	○	○
Increasingly unpredictable spring temperatures (early bud break, late frosts)	○	○	○	○
Wind damage	○	○	○	○
Hail	○	○	○	○
Increasing or new insect pest pressures	○	○	○	○
Increasing weed pressure	○	○	○	○

Experience and Concern about Extreme Weather

The next questions are about your perspective on extreme weather and climate change. Please indicate your level of agreement with the following statements:

Agree or Disagree *Where 1 represents strongly disagree, and 5 represents strongly agree*	1	2	3	4	5
The increased intensity of droughts, storms, and floods is a result of climate change	○	○	○	○	○
Extreme weather events in recent years have affected my long-term farm management goals.	○	○	○	○	○
I am concerned that available best management practice technologies are not effective enough to protect the land I farm from the impacts of climate change	○	○	○	○	○

Optional section

Please indicate your level of agreement with the following statements:

Agree or disagree: *Where 1 represents strongly disagree, and 5 represents strongly agree*	1	2	3	4	5
I have the knowledge and technical skill to deal with any weather-related threats to the viability of my farm operation.	○	○	○	○	○
I have the financial capacity to deal with any weather-related threats to the viability of my farm operation, including crop insurance.	○	○	○	○	○
I understand the vulnerability of my farmland to extreme weather conditions.	○	○	○	○	○
My community and social networks will support my farm in recovering from the severe impacts of weather variability.	○	○	○	○	○
The government should pay my farm for providing ecosystem services, such as carbon sequestration.	○	○	○	○	○

Thank you for taking the survey! Please share your final thoughts and click the validate button at the bottom of the page.

What incentives would most help you make the changes you think you need to make to mange for the risks of extreme weather?

- [ ] Access to appropriate equipment & technology
- [ ] Cost share incentive programs
- [ ] Technical assistance
- [ ] Grants for equip or infrastructure improvements
- [ ] On-farm demonstrations
- [ ] OTHER ______________________________

Is there anything else you'd like to share related to the content of this survey?

____

If you would like to receive a copy of the report based on this survey, please enter your email below. We will not share, disclose or use your email address in any other way.

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Look for our report and listening tour next year. THANK YOU VERY MUCH! ~ Alissa and Team